Remedial Investigation/Feasibility Study of the Soldier Creek/IWTP Groundwater Operable Unit at Tinker Air Force Base

Field Sampling Plan

Final

Prepared for

Oklahoma City Air Logistics Center

Tinker Air Force Base, Oklahoma

May 1994

AU405

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Prepared by

Engineering-Science, Inc.
Austin, Texas

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USAF Contract Number F34650-93-D-0106
Delivery Order Number 5001

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ACRONYMS AND ABBREVIATIONS

AB	Ambient condition blank
AFB	Air Force Base
AIHA	American Industrial Hygiene Association
ASTM	American Society for Testing and Materials
BCHSAMP	IRPIMS database environmental sampling information file
bgl	Below ground level
CAL	Caliper
COC	Chain-of-custody
D	Density
DOT	U.S. Department of Transportation
EB	Equipment blank
EM	Environmental Management Directorate Representative
EPA	U.S. Environmental Protection Agency
ES	Engineering-Science, Inc.
ESP	Environmentalist's Sub-soil Probe
FD	Field duplicate
FR	Field replicate
μg/kg	Micrograms per kilogram
μg/L	Micrograms per liter
FS	Feasibility study
FSP	Field sampling plan
gals/ft	Gallons per foot
GR	Gamma ray
GWTP	Groundwater Treatment Plant
IDW	Investigation-derived waste
IWTP	Industrial wastewater treatment plant
IRP	Installation Restoration Program
IRPIMS	Installation Restoration Program Information Management System
LC	Lithologic core
LEL	Lower explosive limit
LSZ	Lower saturated zone, including an upper and lower subzone
μmhos/cm	Micromhos per centimeter

MB	Materials blank
MCL	Maximum containment level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
mL	Milliliter
MR	Micro-resistivity
MS	Matrix spike
MSD	Matrix spike duplicate
MSL	Mean sea level
MW	Monitoring well
N	Neutron
NA	Not applicable
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute for Occupational Safety and Health
NPL	National Priorities List
NTU	Nephelometric Turbidity Unit
OAC	Oklahoma Administrative Code
OD	Outside diameter
ODEQ	Oklahoma Department of Environmental Quality
OVA	Organic vapor analyzer
OW	Observation well
OWRB	Oklahoma Water Resources Board
PCB	Polychlorinated biphenyl
PEL	Permissible exposure limit
PGS	Partial gaging station
PID	Photoionization detector
POC	Point of contact
ppb	Parts per billion
PPE	Personnel protective equipment
ppm	Parts per million
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
QAPP	Quality assurance project plan
R	Resistivity
RI	Remedial investigation
SB	Soil boring
SCGW	Soldier Creek/IWTP Groundwater Operable Unit
SD	Spike duplicate
SE	Sediment
SOP	Standard operating procedure
SOW	Statement of work
SP	Spontaneous potential

SW	Surface water
TB	Trip blank
TBD	To be determined
TCLP	Toxicity characteristic leaching procedure
TEGD	Technical Enforcement Guidance Document
TWRI	Technologies of Water Resources Investigation of the USGS
USACE	U.S. Army Corps of Engineers
USAF	United States Air Force
USGS	United States Geological Survey
USZ	Perched saturated zone
UTM	Universal Transverse Mercator
UV	Ultraviolet
VOC	Volatile organic compound
WSP	USGS Water Supply Paper
°C	Degrees Celsius
°F	Degrees Fahrenheit

SECTION 1

INTRODUCTION

1.1 INTRODUCTION

Tinker Air Force Base (AFB) has contracted Engineering-Science (ES) to provide all services and supplies necessary to perform a Remedial Investigation/Feasibility Study (RI/FS) on the Soldier Creek/IWTP Groundwater (SCGW) Operable Unit. This field sampling plan (FSP) has been prepared for use during this RI/FS under United States Air Force (USAF) contract number F34650-93-D-0106, delivery order number 5001, and the project statement of work (SOW). The FSP specifies data collection methods to be used during RI/FS field activities.

Tinker AFB is located in Oklahoma County in central Oklahoma, approximately 8 miles southeast of downtown Oklahoma City (Figure 1.1). The base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 (I-40) to the north, and Southeast 74th Street to the south. The base comprises 5,000 acres.

The majority of the SCGW operable unit is located immediately northeast of the base, with a small portion located within the base boundary. Figure 1.2 is a site map. The SCGW includes the groundwater under and adjacent to Soldier Creek where contamination may have originated from the industrial wastewater treatment plant (IWTP)/Building 3001 National Priorities List (NPL) site and groundwater underneath the IWTP. The scope of this focused RI/FS investigation will extend north from the most southern piped outfall from Building 3001 (north of Gate 21) to I-40, west to West Soldier Creek and east to East Soldier Creek.

1.2 PROJECT OBJECTIVES

Previous investigations of Soldier Creek sediment and surface water and of groundwater northeast of the base did not adequately address off-base groundwater contamination. The pertinent findings of these investigations are summarized in the project work plan (ES, 1994a).

The objectives of the RI/FS are to determine whether contaminant releases to Soldier Creek and off-base groundwater have occurred, to determine the nature and extent of the contaminant releases and to assess the groundwater remedial alternatives if the risk assessment warrants. The interaction between the creek and the underlying groundwater reservoirs will also be studied and quantified.

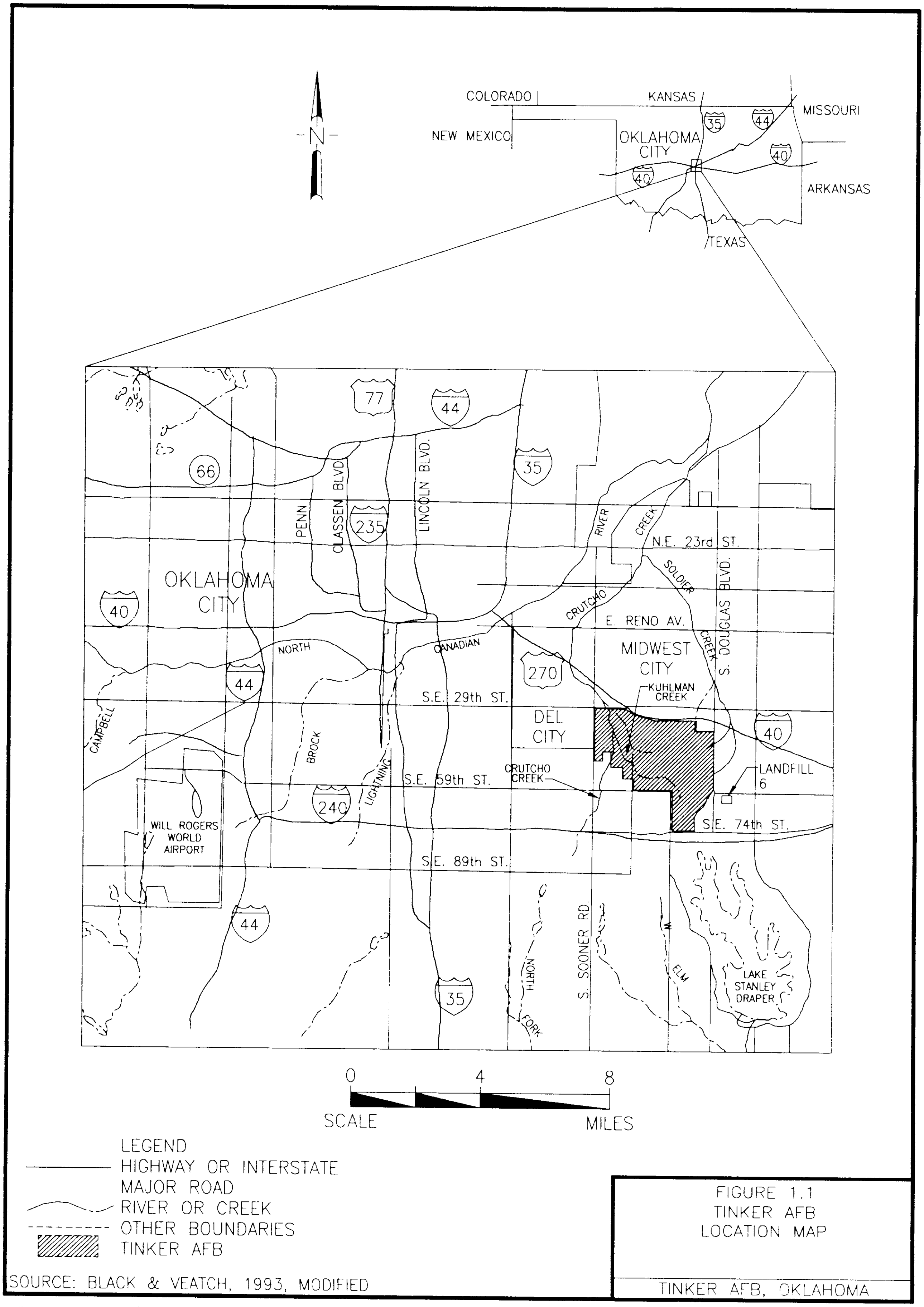

FIGURE 1.1
TINKER AFB
LOCATION MAP

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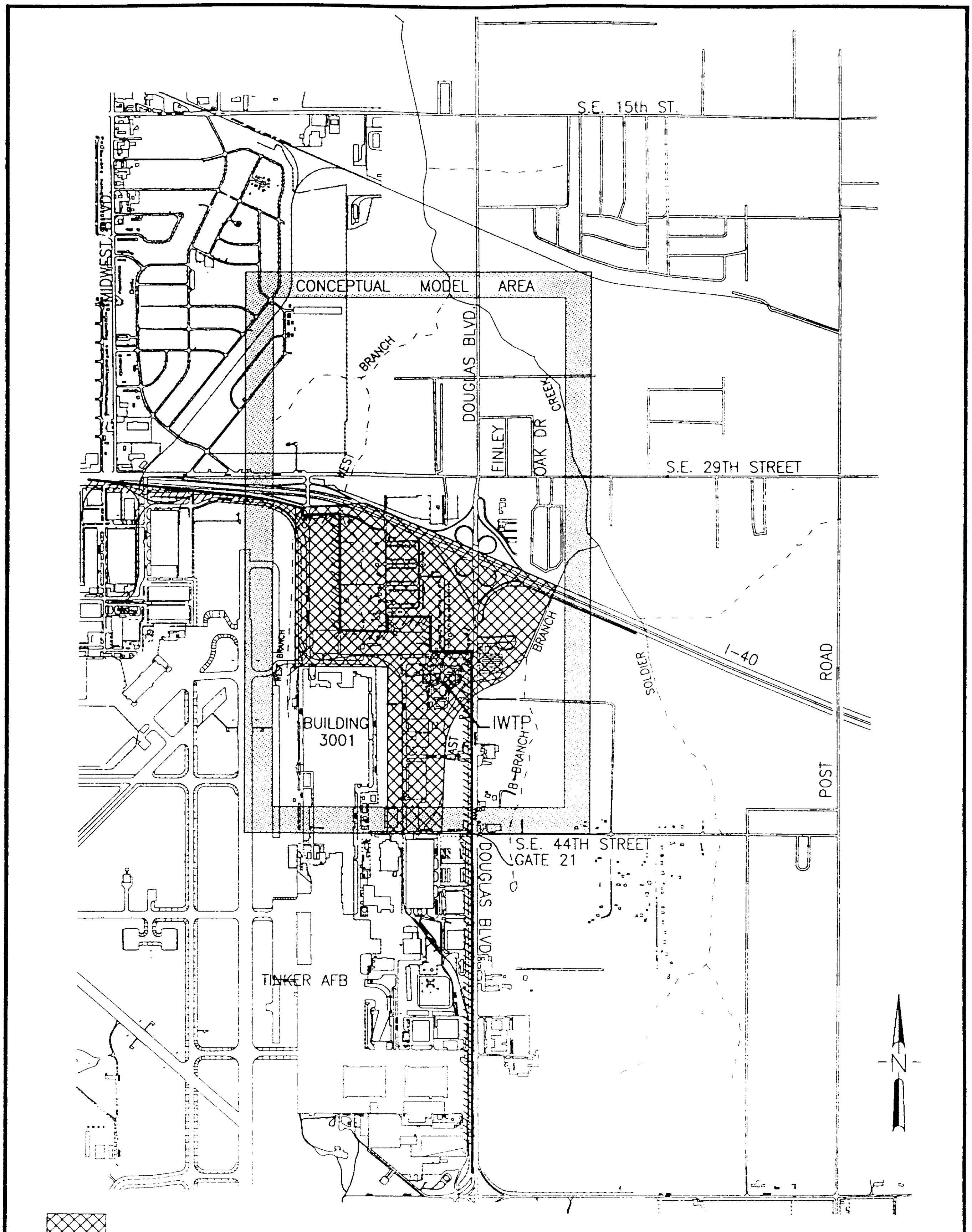


FIGURE 1.2
SCGW RI/FS
SITE MAP

TINKER AFB, OKLAHOMA

This FSP describes ES's approach to characterizing the site, including the number, type, and locations of samples and the type of analyses. This document will be used by field personnel as a guideline for conducting field activities. It is written so that a field sampling team unfamiliar with the site will be able to gather the required samples and field information as suggested in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988).

With this FSP, there are four companion project plans proposed for SCGW RI/FS. These reports are:

- Work Plan (WP) (ES, 1994a)
- Health & Safety Plan (HSP) (ES, 1994b)
- Quality Assurance Project Plan (QAPP) (ES, 1994c)
- Data Quality Objective Plan (DQOP) (ES, 1994d)

1.3 PROJECT SCOPE

The scope of work for this RI/FS, which has been divided into ten tasks, is described in detail in the project WP (ES, 1994a). A brief description of the ten tasks is provided below.

1. Perform a historical review and windshield survey.
2. Sample and geophysically log approximately twelve private wells.
3. Determine daily discharge rates for Soldier Creek, and estimate seasonable direction and volume fluctuations of water moving between Soldier Creek and the underlying aquifer for nine months.
4. Drill four continuous cores to a depth of up to 200 feet each for detailed lithologic information. Perform geophysical surveys of the coreholes and of the cores. Collect twenty-four samples for geotechnical analyses.
5. Drill twelve pilot holes, each to a depth of 180 feet. Install nine monitoring well clusters, three piezometer clusters, and one pumping test cluster, each consisting of three wells/piezometers with approximate depths of 40 feet, 90 feet, and 150 feet. Collect water samples from each of these wells.
6. Develop a conceptual model and fence diagram of the geology and of the groundwater/surface water interactions at the site.
7. Conduct three, 7-day long-term aquifer pumping tests to determine aquifer geohydraulic parameters for the conceptual model. Tests will be performed on the three saturated zones at approximate depths of 40, 90, and 150 feet.
8. Collect soil samples in the vicinity of each of the twelve sampled private wells of Task 2.
9. Collect stream sediment samples at twenty locations in Soldier Creek where groundwater discharges.
10. Analyze groundwater samples for 129 priority pollutants, excluding dioxin and asbestos. Analyze soil and sediment samples for EPA Target Compound List (TCL) analytes (except pesticides), arsenic, barium, cadmium, chromium

(total and hexavalent), copper, mercury, nickel, lead, selenium, silver, and zinc.

The field methods to be used to complete these tasks are described in this document.

SECTION 2

FIELD OPERATIONS

In this project, private wells will be geophysically logged and sampled, deep cores will be taken, monitoring wells will be installed, samples of groundwater, soil, and sediment will be collected for chemical analysis, borehole geophysical surveys will be conducted, aquifer pumping tests will be completed, and other associated field operations will be carried out. Many field activities have widely recognized standard procedures, such as American Society for Testing and Materials (ASTM) methods for soil sampling from borings, while others allow great latitude in techniques. The equipment required for the various activities ranges in complexity from tape measures and shovels to digital data recorders for water level measurements. ES has developed field procedures to ensure that field activities at the study site is performed in a consistent manner that meets quality assurance/quality control (QA/QC) objectives.

The field procedures described in this section were developed to incorporate standard procedures, such as those in the U.S. Environmental Protection Agency (EPA) *Compendium of Superfund Field Operations Methods* (EPA, 1987) and Engineering-Science's "Field Services Manual" (ES, 1992).

Standard forms will be used for documentation of borehole logging, monitoring well construction, most field sampling operations, and equipment calibration. Bound field logbooks will be used to record daily field activities and events. Procedures for logbook documentation and examples of standard forms to be used are presented in Section 6.

2.1 SITE RECONNAISSANCE, PREPARATION, AND RESTORATION PROCEDURES

All necessary ES personnel and their subcontractors will obtain a visitor's pass at the main gate before entering Tinker AFB. The ES program manager will provide these personnel with letters which will authorize their admittance onto the base.

A field office will be located within the vicinity of the site investigation area. A fire extinguisher and first aid kit will be available in the field office and in each field vehicle and will be transported to each site where field activities are being performed. All other personal safety equipment such as protective clothing and respirators will be stored in the field office. All hazardous chemicals will be stored in a fire-resistant cabinet. The HSP may be referred to for further information on health and safety issues (ES, 1994b).

Decontamination of equipment used during the investigation will take place at decontamination pads set up specifically for this purpose. Upon approval by Tinker AFB, decontamination fluids will be discharged to the IWTP or the groundwater treatment plant (GWTP). Fluids which cannot be disposed of at the IWTP or GWTP will be disposed in accordance with all applicable laws and regulations. Engineering-Science (ES) will arrange for disposal of waste materials and fluids which cannot be treated on base.

The exact locations of boreholes and monitoring wells will be determined in the field by ES in consultation with Tinker AFB. Underground and aboveground utility lines, buildings, and natural features will be considered in choosing these drilling locations. Ambient air conditions will be monitored for organic vapors before and during drilling to ensure that no health and safety concerns exist at the site.

Efforts will be made to minimize disturbance at all field activity sites. All trash will be removed from the site. All sites will be restored to their original conditions.

2.2 PRIVATE WELL SURVEY

Approximately twelve wells identified during the historical review and wind shield survey will be geophysically logged and sampled. Figure 2.1 shows the location of the twelve domestic wells to be logged and sampled. The wells, with maximum estimated depths of 200 feet each, will be geophysically logged by a subcontractor, as outlined in Section 2.6, with Natural Gamma Ray (GR) and Caliper (CAL) tools to acquire geological and well construction information. A downhole television camera survey will record the condition of the existing casing and determine or substantiate well design and conditions. All equipment used during the geophysical logging that comes into direct contact with the wells will be decontaminated by the methods outlined in Section 2.9.

Once the logging has been completed at all of the wells, groundwater samples will be collected from each well. In addition, soil samples will be collected in the vicinity of each well. Procedures for groundwater and soil sampling are described in Section 3.1.

Information gathered during this private well survey will be listed on a Well and Pump Data form (Figure 2.2). Each of these wells will be surveyed by a subcontractor as described in Section 2.8.

Tinker AFB will secure access agreements (right-of-entry) sufficient for the contractor to complete this task. Obtaining these agreements will take approximately six weeks.

2.3 SOLDIER CREEK STREAMFLOW SURVEY

The Soldier Creek Streamflow Survey has three goals:

1. Determine the Soldier Creek hydrologic regime for nine months.

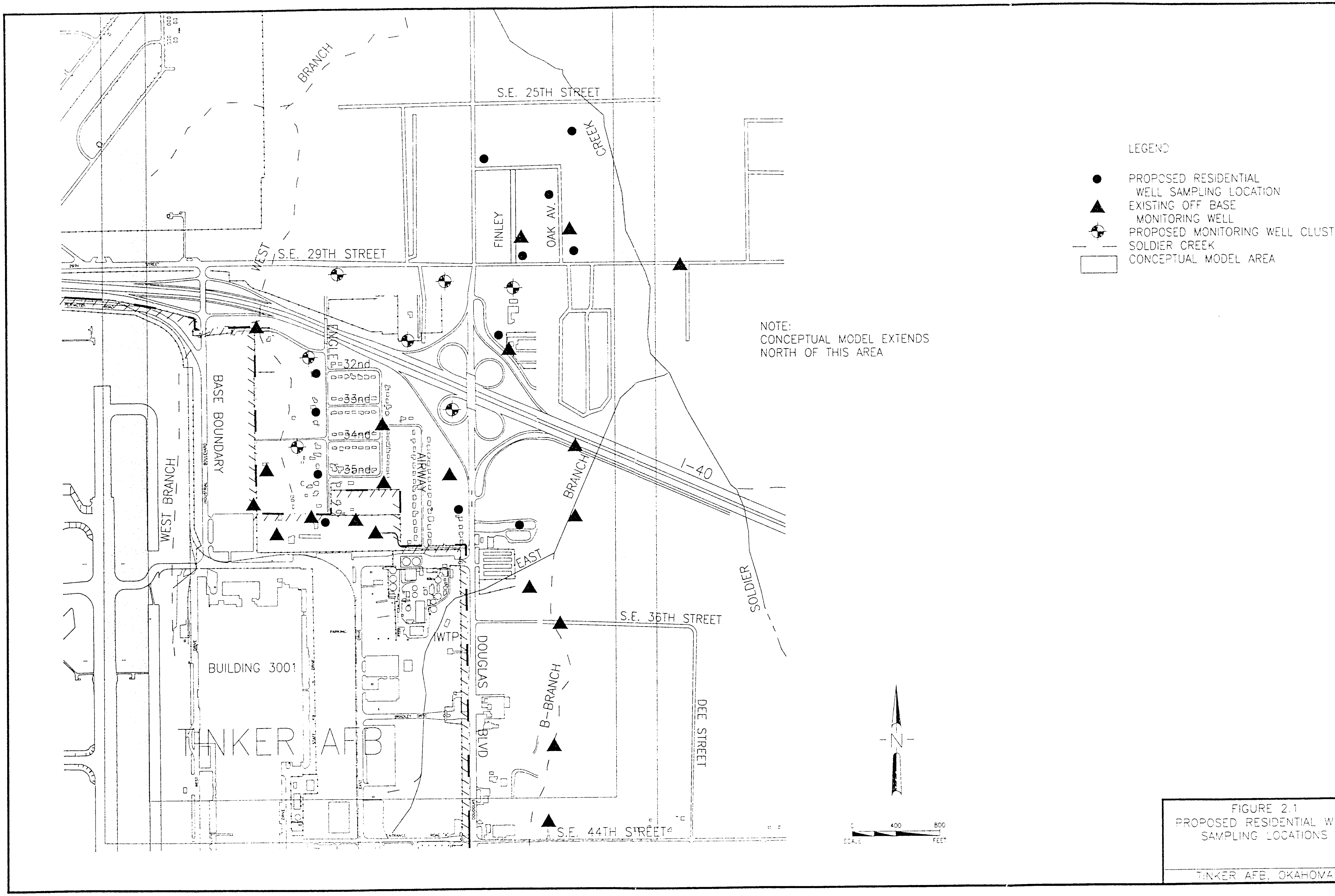


FIGURE 2.1
PROPOSED RESIDENTIAL W
SAMPLING LOCATIONS

TINKER AFB, OKAHOMA

GWLOC 5/24/94

Figure 2.2 **WELL AND PUMP DATA**

ocation of Well

County	Township Number N or S	Range Number E or W	Section No.	Fraction
wnship				¼ ¼ ¼

reet Address and City or Distance and Direction from Road Intersections

Property owner's name and address

ow exact location of well in section grid with an 'x' **Sketch map of well location**

N

S

1 mile

Addition Name

Block Number

Lot Number

Well depth **Datum point from which all measurements are taken**

Method of Drilling
☐ Cable tool ☐ Hollow rod ☐ Driven ☐ Dug
☐ Direct rotary ☐ Air rotary ☐ Bucket auger ☐ ______
☐ Reverse rotary ☐ Jetted ☐ Flight auger

Use
☐ Domestic ☐ Public supply ☐ Industrial ☐ ______
☐ Irrigation ☐ Municipal ☐ Commercial
☐ Test Well ☐ Heating or cooling ☐ Monitoring

Casing Type
☐ Steel ☐ Threaded Height above/below
☐ Galv ☐ Welded surface ______
☐ PVC ☐ Solvent welded Drive shoe? Yes ___ No ___
☐ SS

Hole diameter

______ in to ______ ft Wgt ____ lb/ft Sch No ____ | ____ in to ____ ft
______ in to ______ ft Wgt ____ lb/ft Sch No ____ | ____ in to ____ ft
______ in to ______ ft Wgt ____ lb/ft Sch No ____ | ____ in to ____ ft

emarks, Elevation, Source of Data, etc.

Intake Portion of Well
Screen type ______ or open hole from ____ ft to ____ ft
Manufacturer ______
Material ______ Dia ______
Fittings ______ Length ______
Set between ____ ft and ____ ft Slot ______
____ ft and ____ ft Slot ______
____ ft and ____ ft Slot ______
Method of installation ______

orehole data

Formation Log	Color	Hardness	From	To

Filter Pack
Source ______ Gradation ______
Method of installation ______ Composition ______
Volume used ______ Depth to top of f p ______

Grout
Used? ☐ Yes ☐ No Volume used ______
☐ Neat Cement ☐ Bentonite ☐ ______
Method of installation ______
Depth from ______ ft to ______ ft
from ______ ft to ______ ft

Development
Method ______ Duration ______
Dates ______ Sand content after ___ hrs ______
Chemicals used ______

Static Water Level
______ ft ☐ below ☐ above grade
Date measured ______

Pumping Water Level
______ ft ☐ below ☐ above grade Date ______
After ______ hrs pumping at ______ gpm

Specific Capacity
______ gpm/ft of drawdown at ______ hours
Date ______

Pump
Date installed ______ Type ______
Manufacturer ______ Model No ______
H P ______ Volts ______ Capacity ______
Depth of pump intake setting ______ No of stages ______
☐ Oil ☐ Water lubrication Power source ______
Material of drop pipe ______ bowls ______
shafting ______ impellers ______ Bowl dia ______
Column pipe dia ______ Length ______ Modifications ______

Well Head Completion
☐ Pitless adaptor ☐ Basement offset Distance above grade ______

Nearest Sources of Possible Contamination
______ ft Direction ______ Type ______
Well disinfected upon completion? ☐ Yes ☐ No

Geophysical Logs Run

ontractor Name and Address

Name of Driller ______
State License Number ______

Water Quality
Sample taken? ☐ Yes ☐ No
Where analyzed ______

Date well completed ______

Source: Driscoll, 1989

2. Determine the influent or effluent reaches along Soldier Creek and other associated vertical hydraulic gradient.
3. Determine the creek bed seepage rate.

To achieve the first goal, two continuous gaging stations will be installed in addition to the six existing gaging stations along Soldier Creek. Each gaging station will have a water level (stage) recorder which will digitally record the water surface elevation. Several discharge measurements will be taken to establish a rating curve for the gaging station. Finally, the average daily stage will be converted to daily discharge. Figure 2.3 shows the six existing gaging stations and the two proposed gaging stations.

2.3.1 Installation of Water-Level Recorder

Construction of the new water-level recording stations will be consistent with techniques used to install the existing stations. Competent structures (bridges, etc.) will be used, if possible, to secure the recorders. Permission of the property owner will be obtained through Tinker AFB personnel before installation occurs. In the event that suitable structures are not available, the recorders will be mounted on sturdy posts and secured in the ground with an adequate concrete base. Figure 2.4 depicts a typical recorder installation on a secure post with the transducer fixed inside a well point. Each station will consist of the following: Leupold and Stevens Model 420 Recorder, Submersible Depth Transmitter II, Stevens Data Card, rechargeable gel-cell battery, weather resistant enclosure, and a RS-232 serial interface cable for downloading data. Each recorder will be mounted on a secure post or permanent structure. The pressure transducer will be installed using a design that allows for easy removal in the event the transducers require cleaning or calibration. The instrument shelter will be made of steel and securely mounted in order to minimize damage or loss due to vandalism and natural forces such as debris being swept downstream during flood events. Gaging station instrumentation is further described in *Stage Measurement at Gaging Stations* (Buchanan and Somers, 1982) and the supplier (Leupold and Stevens, Inc.) manual.

2.3.2 Discharge Measurements at Gaging Station

A current meter measurement is the summation of the products of the partial areas of the creek cross-section and their respective average velocity (Buchanan and Somers, 1969). The midstream method of a current meter measurement assumes the velocity sample at each location (partial area) represents the mean velocity in a partial rectangular area (Figure 2.5). This area extends laterally from half the distance from the preceding meter location to half the distance to the next, and vertically from the water surface to the sounded depth. Corbett (1943), Rantz (1982), and Buchanan and Somers (1969) recommend that the stream cross-section be divided into at least twenty-five or more partial areas so that no one partial area will account for more than 5 percent of the total discharge.

At flat streambed locations with extremely low flow and water depth of less than 4 inches, the flow measurement with a current meter is not feasible. Other discharge measuring instruments or methods such as portable weir plates, Parshall

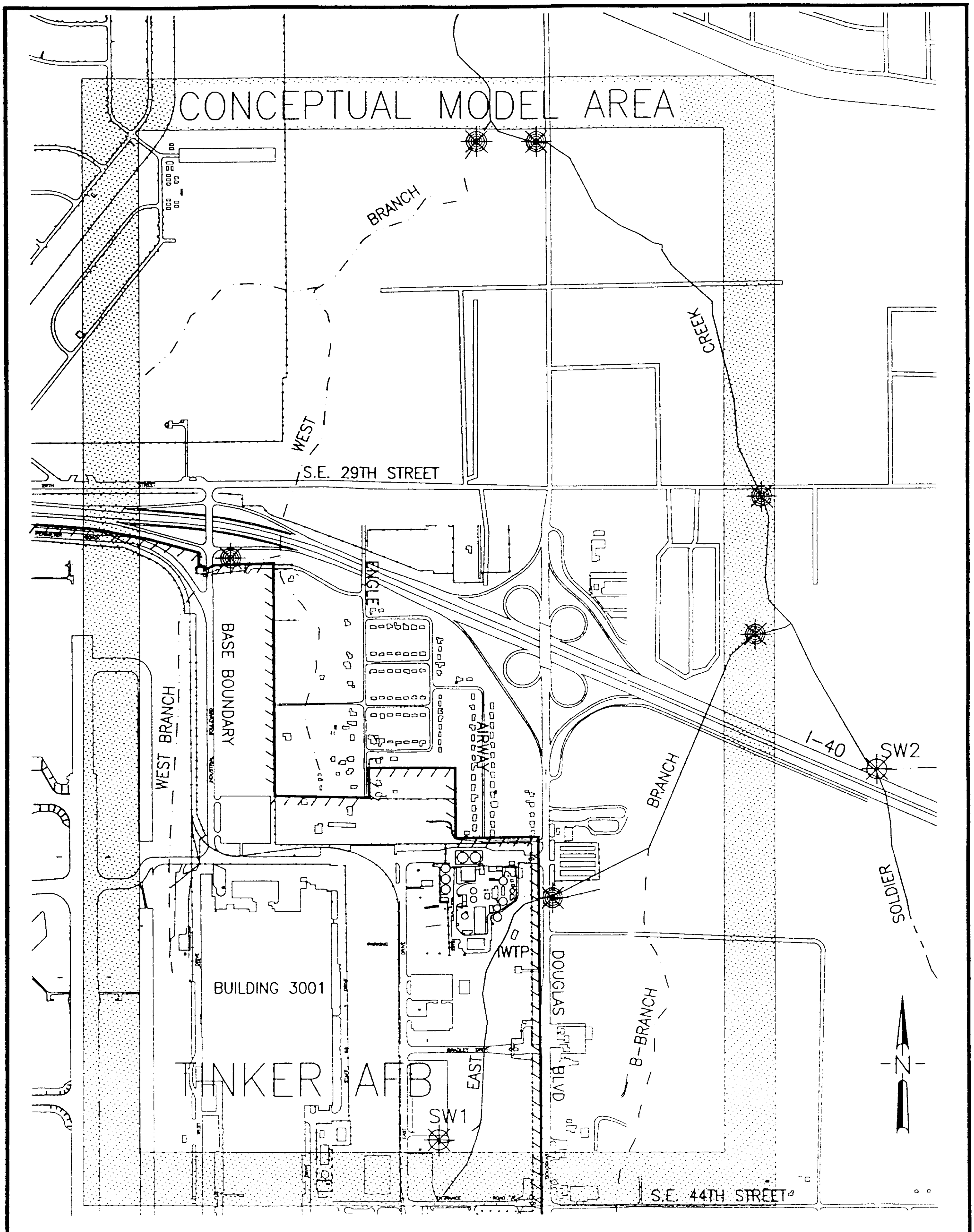


FIGURE 2.3
PROPOSED
STREAM GAGING STATIONS

TINKER AFB, OKLAHOMA

GAC: 5/24/94

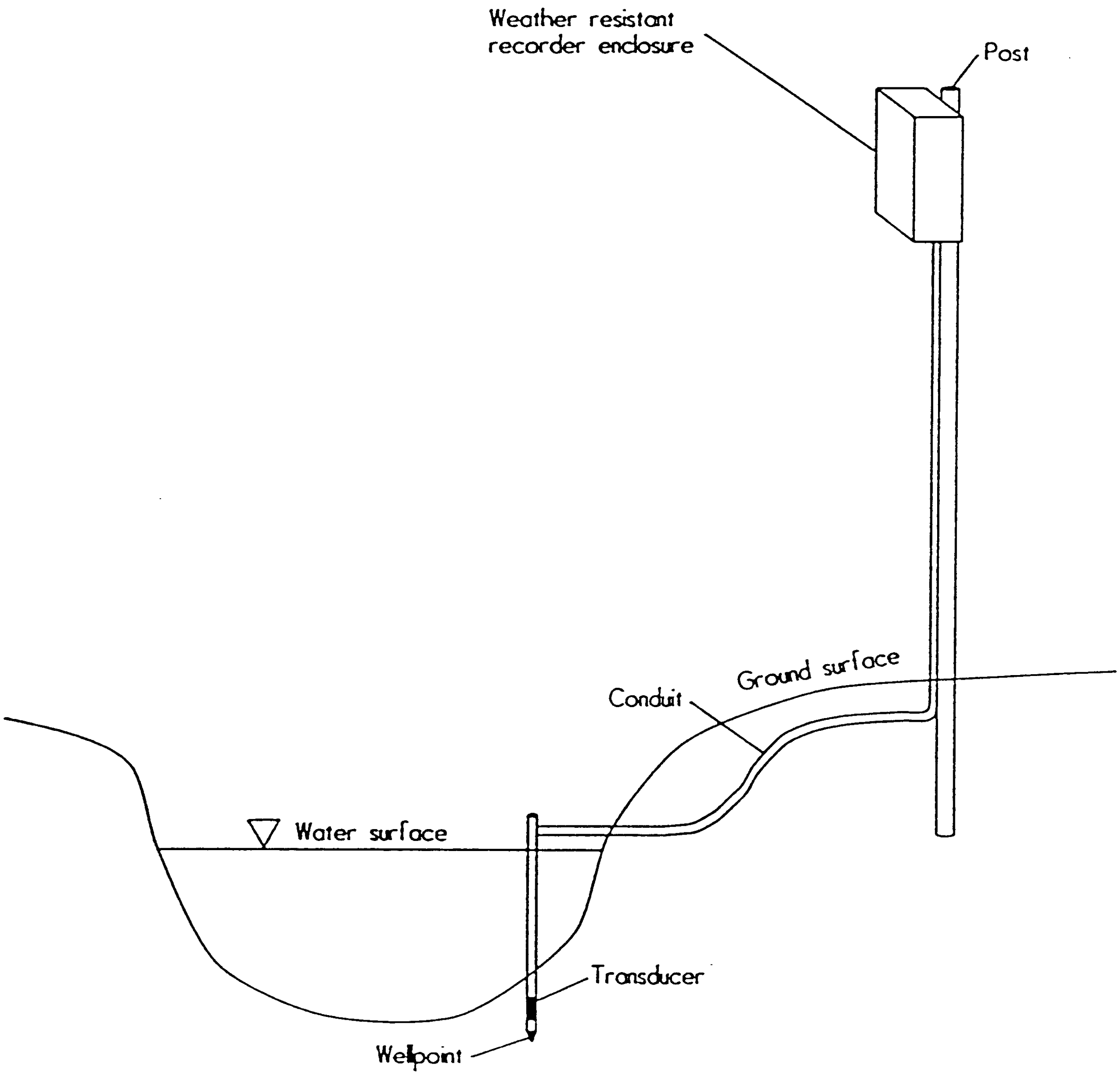
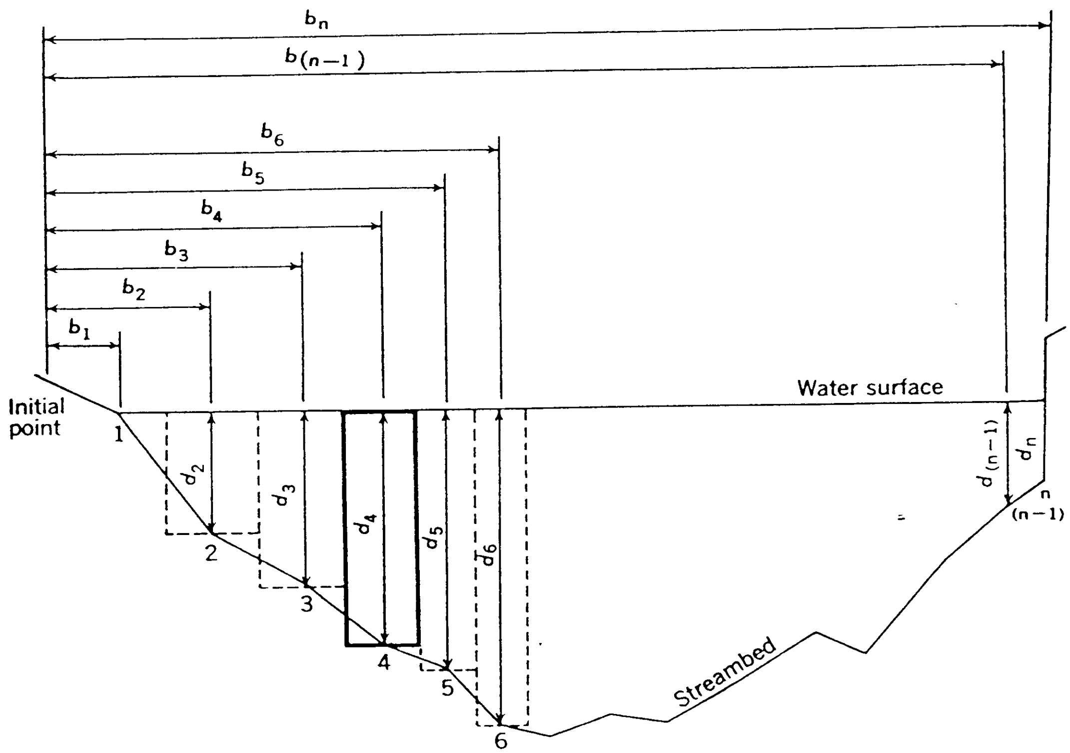


FIGURE 2.4
TYPICAL STREAM
GAGING STATION

TINKER AFB, OKLAHOMA

SOURCE: BATTELLE, 1993



EXPLANATION

1, 2, 3, ... *n*	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the obse,vation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

SOURCE: BUCHANAN & SOMERS 1976
RANTZ, 198[illegible]

FIGURE 2.5
DIVISION OF STREAM INTO
OBERVATION INTERVALS
FOR DISCHARGE MEASUREMENTS

TINKER AFB, OKLAHOMA

[illegible]/24/94

flume, volumetric, float, or dye-dilution will be used. These methods are discussed in Buchanan and Somers (1969) and U.S. Geological Survey's Techniques of Water Resources Investigations (TWRI) Book 3, *Applications of Hydraulics*.

Instrumentation

Current meters, timers and counting equipment are used when gaging streams. A Price type AA and a Price "pygmy" current meter will be used. These meters are used extensively by the USGS. The meter supplier provides a current meter rating table or equation to convert revolutions per time to velocity.

If the creek is wadable, a top-setting wading rod will be used. Use of the wading rod is described in *Discharge Measurements of Gaging Stations* (Buchanan and Somers, 1969). During high flow when wading is impossible, the current meter may be attached to a sounding weight and a sounding reel. The current meter is then lowered down into the creek from a bridge or cableway. The distance to any point in a cross-section is measured from an initial point on the bank. For measurements made by wading, steel tape or tag lines are used. In narrow channels where sagging is not a problem, a fiberglass tape may be used in lieu of tag lines.

Measurement of Velocity

The current meter measures velocity at a point. The discharge measurement at a cross-section requires determination of the mean velocity in each of the selected vertical sections. The mean velocity is obtained from velocity measurements at many points in that vertical section as shown in Figure 2.5. The methods of measuring velocity are:

Method	Meter	Conditions
0.2 and 0.8 depth	Type AA	• USGS preferred method for water depth greater than 2.5 feet
0.6 depth	Type AA	• When depth is between 1.5 feet and 2.5 feet
		• When a large amount of ice or debris is present, preventing the 0.2 depth method.
		• When a sounding weight is used that makes 0.8 depth method impossible
		• When the stream stage changes rapidly and a measurement must be made quickly
0.6 depth	Pygmy	• When depth is 0.3 to 1.5 feet.

Generally, the hydrologist/hydrographer will stretch a tag line across the creek from bank to bank. The tag line should be taut and perpendicular to the stream flow. The tag line will be divided into twenty-five intervals for current-meter measurements based on the width of the water surface. No interval should contain discharge more than 5 to 10 percent of the entire cross-section. The deepest part and the swiftest part of the creek may have a shorter interval while the shallow and low-flow portion may have a wider interval. A Price Pygmy meter will be used for low and moderate flow conditions (0.1 to 4.9 feet per second).

The hydrologist will face the bank upstream and hold the current-meter mounted wading rod vertical and about 18 inches upstream but 1 to 3 inches downstream from the tag line. The current meter will be set at 0.2 and 0.8 depths for water deeper than 2.5 feet and at 0.6 depth for water depths between 1.5 to 2.5 feet. The revolutions will be counted for 60 seconds and recorded on USGS form 9-275, Discharge Measurement notes. This form is included in Section 6.

The methodology described above follows the USGS standard operation procedure (SOP) for velocity measurement (Buchanan and Somers, 1969 and Rantz, 1982). USGS also has discharge measurement SOPs to handle other situations such as deep and swift streams, iced over streams, measurements over bridges, and flood peak measurements.

Discharge Rating

The discharge computed from the discharge measurement notes form is tabulated on USGS form 9-207, Discharge Measurement Summary Sheet, for each gaging station. Step-by-step procedures for converting discharge measurement data to discharge stage rating curves for stable channels and methods for adjusting the measured discharge for unstable channels are described in *Computation of Continuous Records of Streamflow* (Kennedy, 1983).

In rare occasions, stream gaging will coincide with a flood peak that is registered by the automatic water level recorder. Indirect method, e.g., Manning's equation, may have to be used to extend the rating curve.

Computation of Continuous Record

The mean daily gage height can be computed from data collected by an automatic water level recorder (Kennedy, 1983). Based on the mean gage height and the stage-discharge rating curve, the daily average streamflow is derived. For Task 3, a computer program provided by Leupold and Stevens, the manufacturer of the water level recorders, will be used to calculate discharge values from the water level and rating curve data. The program will also sum the daily, weekly, and monthly discharge at each gaging station.

2.3.3 Streambed Hydraulic Conductivity Measurements

The vertical hydraulic conductivity of the streambed and the relative hydraulic gradient between the stream and the underlying alluvial material will determine the direction and quantity of water that moves between the stream and the aquifer. State-of-the-art measurement techniques can be employed to directly measure the hydraulic conductivity of the streambed and the hydraulic gradient across the sediments. All reaches of Soldier Creek within the SCGW conceptual hydrologic model area will be examined for potential measurement sites. The water depth, thickness of the alluvium, and access to the stream are all factors that will be considered when selecting measurement locations. Figure 2.6 shows the six stream

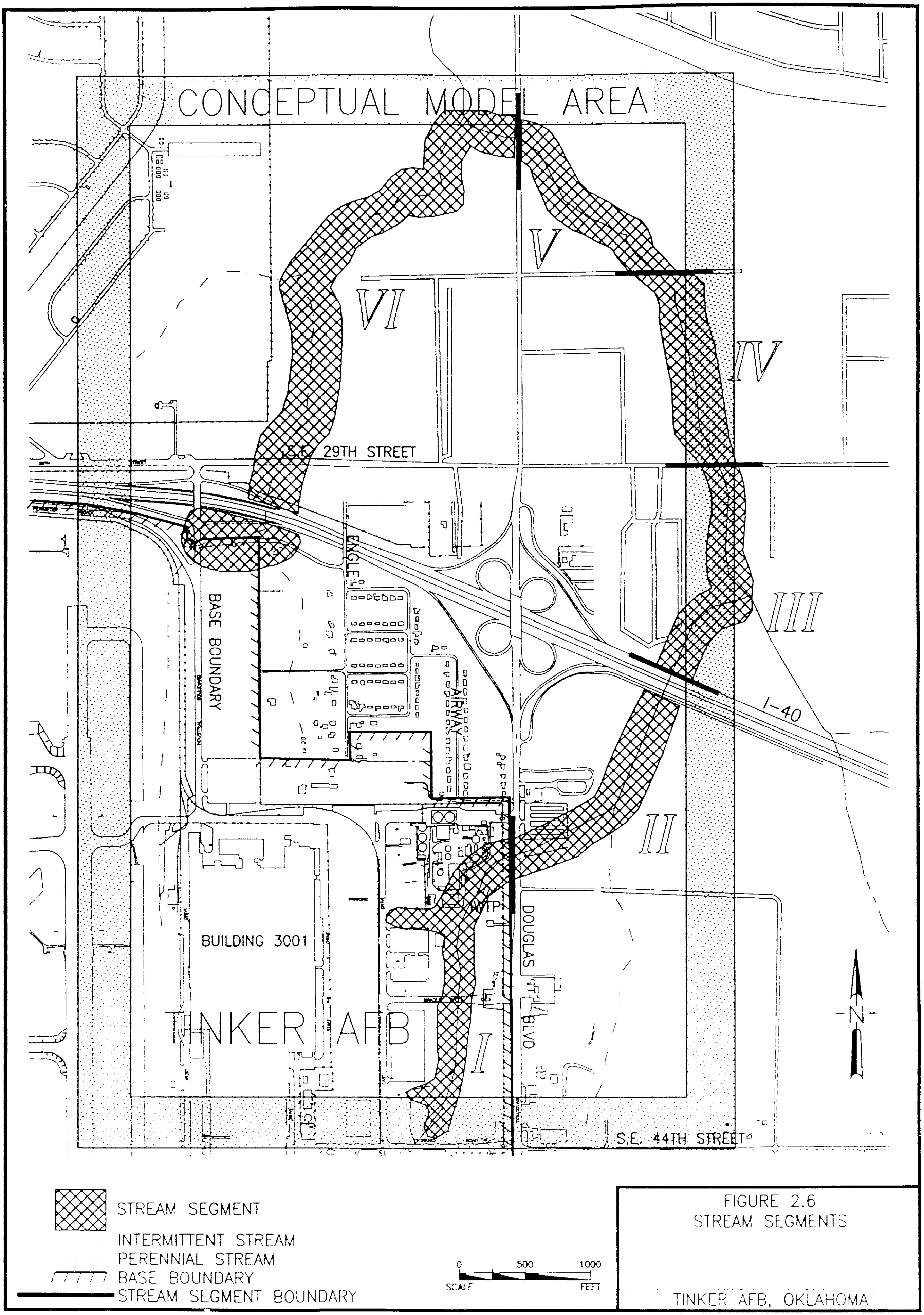


FIGURE 2.6
STREAM SEGMENTS

TINKER AFB, OKLAHOMA

segments. Streambed permeability will be tested for each of the six segments. These locations will coincide with the piezometers that will be measured every three months to observe seasonal effects on the hydraulic gradient across the streambed.

The method and equipment used to measure streambed hydraulic conductivity is described by Lee and Cherry (1978) and Payne (1992). This method uses a miniature piezometer to measure the hydraulic gradient across the streambed and a seepage meter to measure the flux (Figure 2.7). The miniature piezometer consists of 3/16-inch-OD polyethylene tube with a perforated tip that is wrapped in surgical gauze. The seepage meter is a 8-inch segment cut from the end of a new 55-gallon drum. If the water level in the piezometer is higher than the stage, the Intravenous (IV) bag will be installed empty to the cut off drum. The volume of the IV bag water divided by the drum area and the time of accumulation gives the upward seepage rate. If the piezometer water level is lower than the stream stage, an IV bag with a known volume of water can be installed to the cut off drum. The change of the water volume in the IV bag during a time period divided by the drum area gives a downward seepage rate. The downward seepage rate may not be exactly equal to the upward seepage rate even at the same location due to anisotropy caused by sedimentation of stream and bedrock.

The hydraulic conductivity measurements will be recorded on field computation sheets and collected in a file. The data will be compiled on a spreadsheet at the end of the data collection and recalculated for comparison with the field results. Each installation of the permeameter is tested with three measurement replicates to ensure reasonable repeatability of the results. The hydraulic conductivity values are also compared to published values to insure they are reasonable for the type of material being tested.

2.3.4 Streambed Vertical and Hydraulic Gradient Study

Six locations will be selected for hydraulic conductivity testing. At each of these sites three piezometers will be installed (conditions permitting) and measured quarterly, i.e., a total of 72 measurements. The piezometers will be installed to different depths in order to observe the hydraulic gradient across the streambed and perhaps across the very top portion of the underlying aquifer. If possible, the piezometers will be protected with a steel surface casing and re-used for each of the quarterly measurements. It is likely that the piezometers will not be usable after three months of exposure in the streambed, especially during periods of high streamflow. In the event the piezometers are not usable, new piezometers will be installed in a nearby location. The exact location of the piezometer clusters will be determined during future reconnaissance surveys of the stream. The locations will be spatially distributed and placed with the intent to collect the most representative values for each stream segment. Equipment similar to the miniature piezometers used in the hydraulic gradient measurements will be used in this investigation.

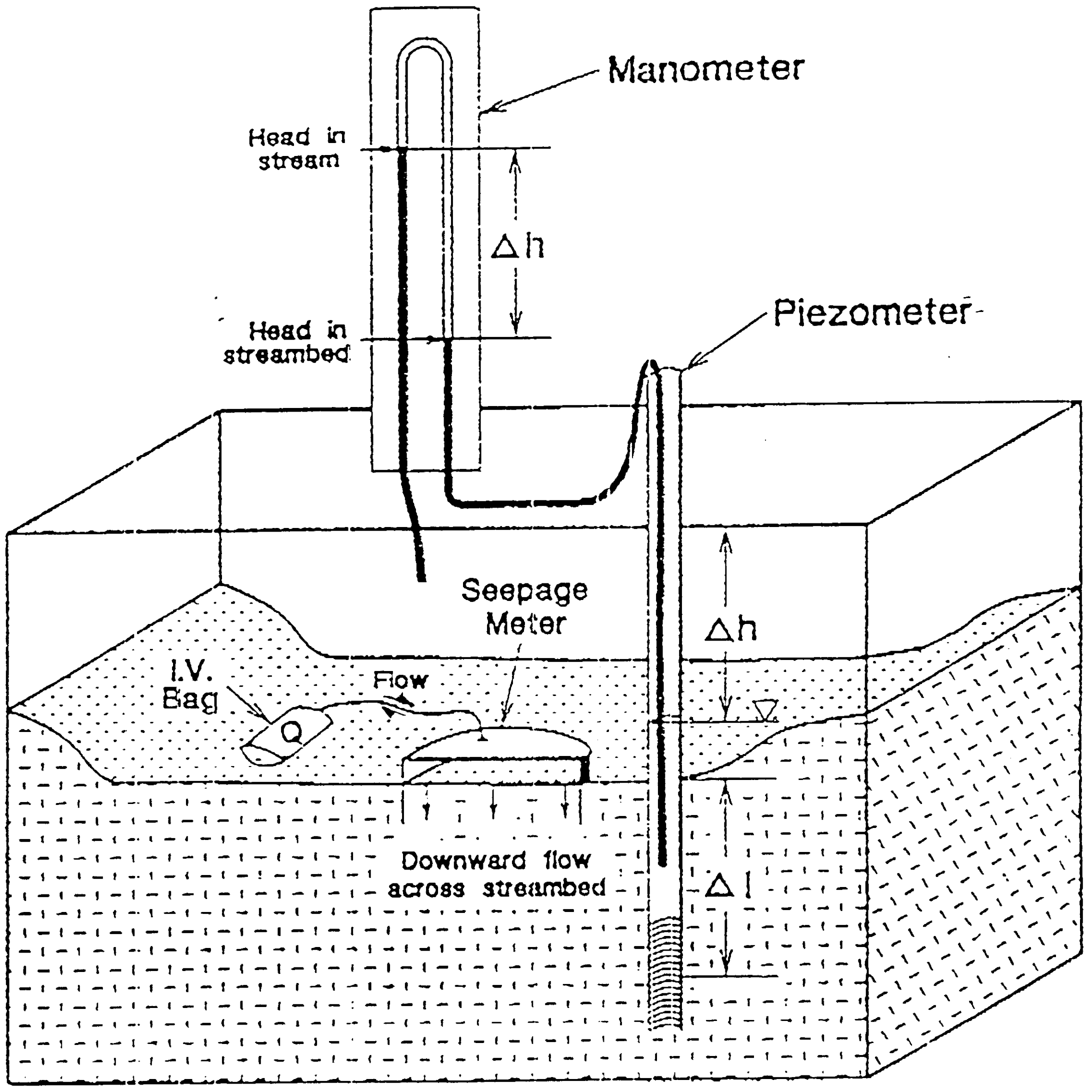


FIGURE 2.7
SCHEMATIC OF
STREAMBED SEEPAGE
METER INSTALLATION

TINKER AFB, OKLAHOMA

2.4 BOREHOLE DRILLING, LITHOLOGIC SAMPLING, AND LOGGING

A maximum of four 200-foot continuous cores and thirteen pilot holes are scheduled to be drilled, and a total of thirty-nine monitoring wells/piezometers will be installed. Proposed locations of the deep cores are shown on Figure 2.8. Monitoring wells/piezometers include twelve clusters of three wells each with depths of approximately 40, 90, and 150 feet below ground level (bgl). Proposed locations for these monitoring well/piezometer locations are shown on Figure 2.9. Pilot holes will be drilled to a depth of 180 feet each prior to the drilling of the monitoring well cluster bore holes. One additional pilot hole and three-well cluster will be drilled at the location shown on Figure 2.10 for use during the aquifer tests.

A geologist will be present and responsible at each operating drill rig for the logging of samples, monitoring of drilling operations, recording of water losses or gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures. Each geologist will be responsible for only one operating rig and will have, as a minimum, a copy of the WP, FSP, and the HSP. They will also have on-site their own 10X hand lens, weighted steel tape, water level measuring device, and the necessary materials to decontaminate the water level measuring device. The geologist will log the lithology of the four coreholes and the thirteen 180-foot pilot holes, as described in Section 2.4.3.

In areas where the groundwater gradient is known, the pilot hole will be placed in the most downgradient position and the shallow well will be placed in the most upgradient position. The deepest well will be placed next to the pilot hole. The wells will be placed 10 feet apart. An effort will be made to place the wells in a relatively flat location so that the elevation difference between individual well locations is minimized. Significant elevation differences between individual well locations will be noted so that proper correlation with the pilot hole can be made.

Hollow stem auger techniques will be used to drill the shallow wells. The equipment used for this method of drilling includes a mechanically powered drill rig which simultaneously rotates and advances a hollow stem auger column. Lithologic samples are obtained with a core barrel attached to a wire line or drill rods.

Depending on site conditions, air or hydraulic rotary drilling methods will be used to drill bore holes to depths greater than 100 feet or when drilling through saturated zones. The air-rotary method will be attempted, but it may be necessary to switch to hydraulic-rotary drilling to retrieve samples, based on the experience of previous contractors (USACE, 1991). In rotary drilling, the borehole is advanced by rapid rotation of the drilling bit, which cuts, chips, and grinds the material at the bottom of the hole into small particles. Air or water from an approved source will be forced into the cutting zone, cooling the zone and flushing cuttings to the surface. A Christenson core barrel will be used to collect samples for chemical or geotechnical analysis following ASTM D2113, "Practice for Diamond Core Drilling for Site Investigation."

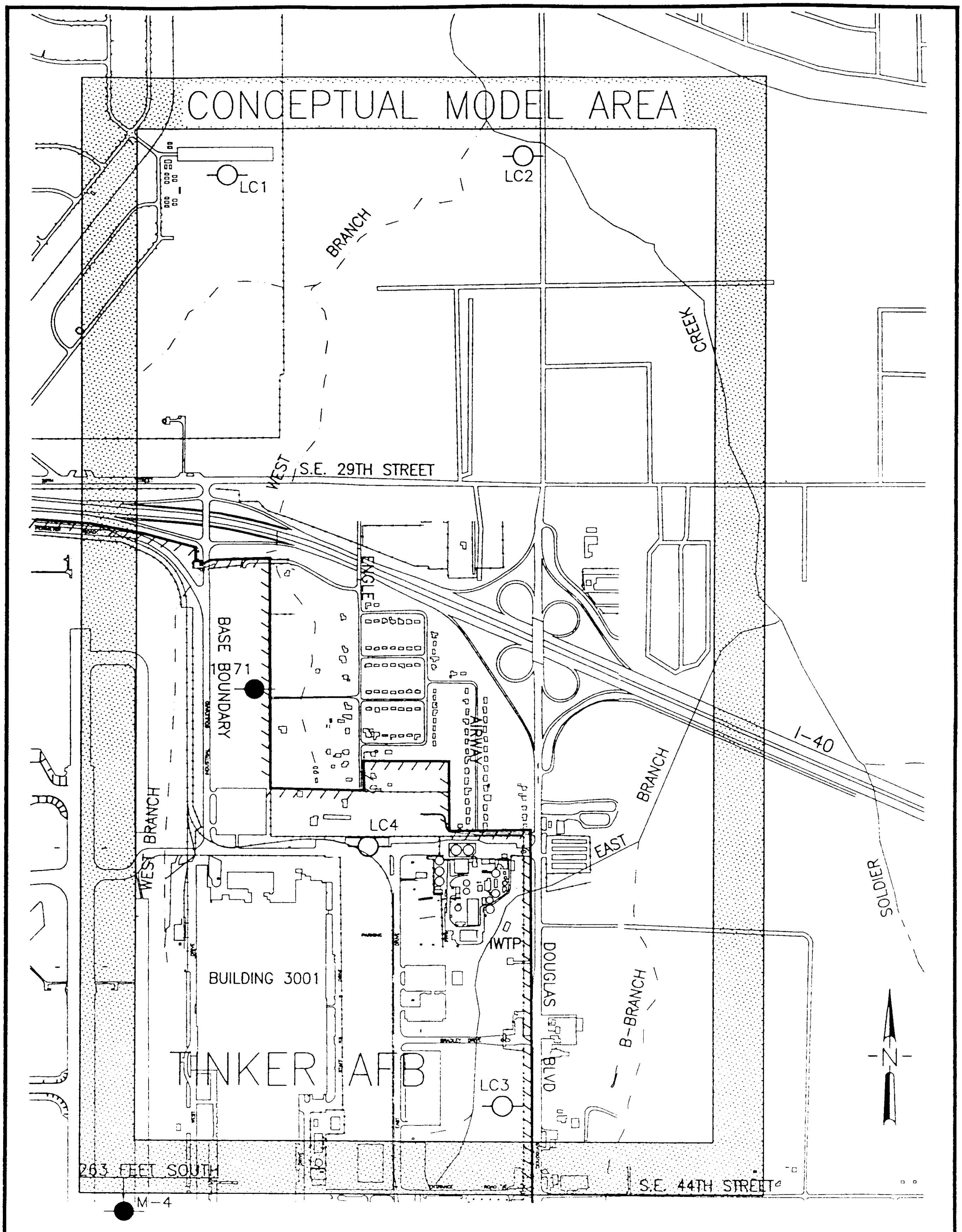


FIGURE 2.8
PROPOSED LOCATION OF
LITHOLOGIC CORINGS

TINKER AFB, OKLAHOMA

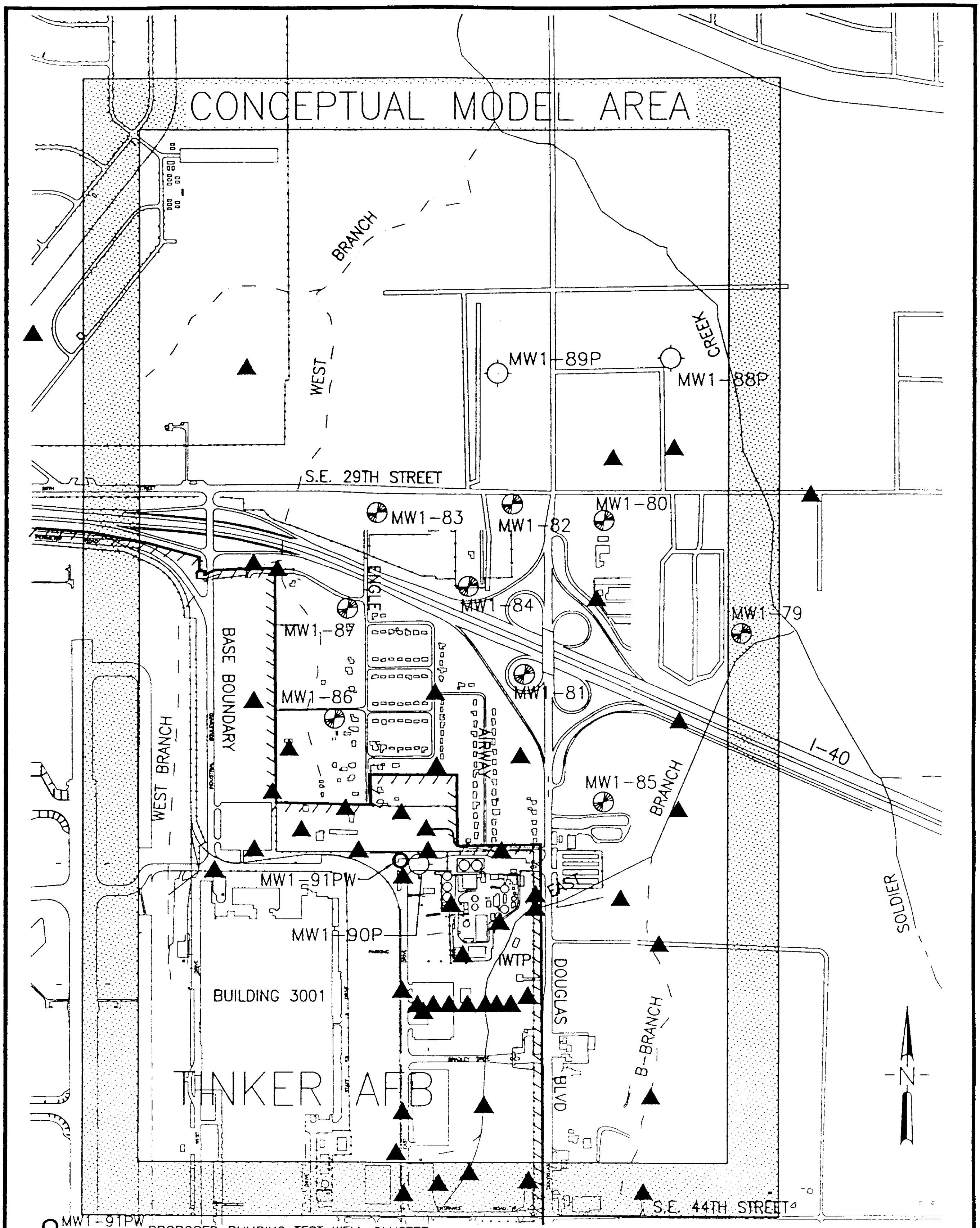


FIGURE 2.9
PROPOSED LOCATIONS OF
MONITORING WELLS

TINKER AFB, OKLAHOMA

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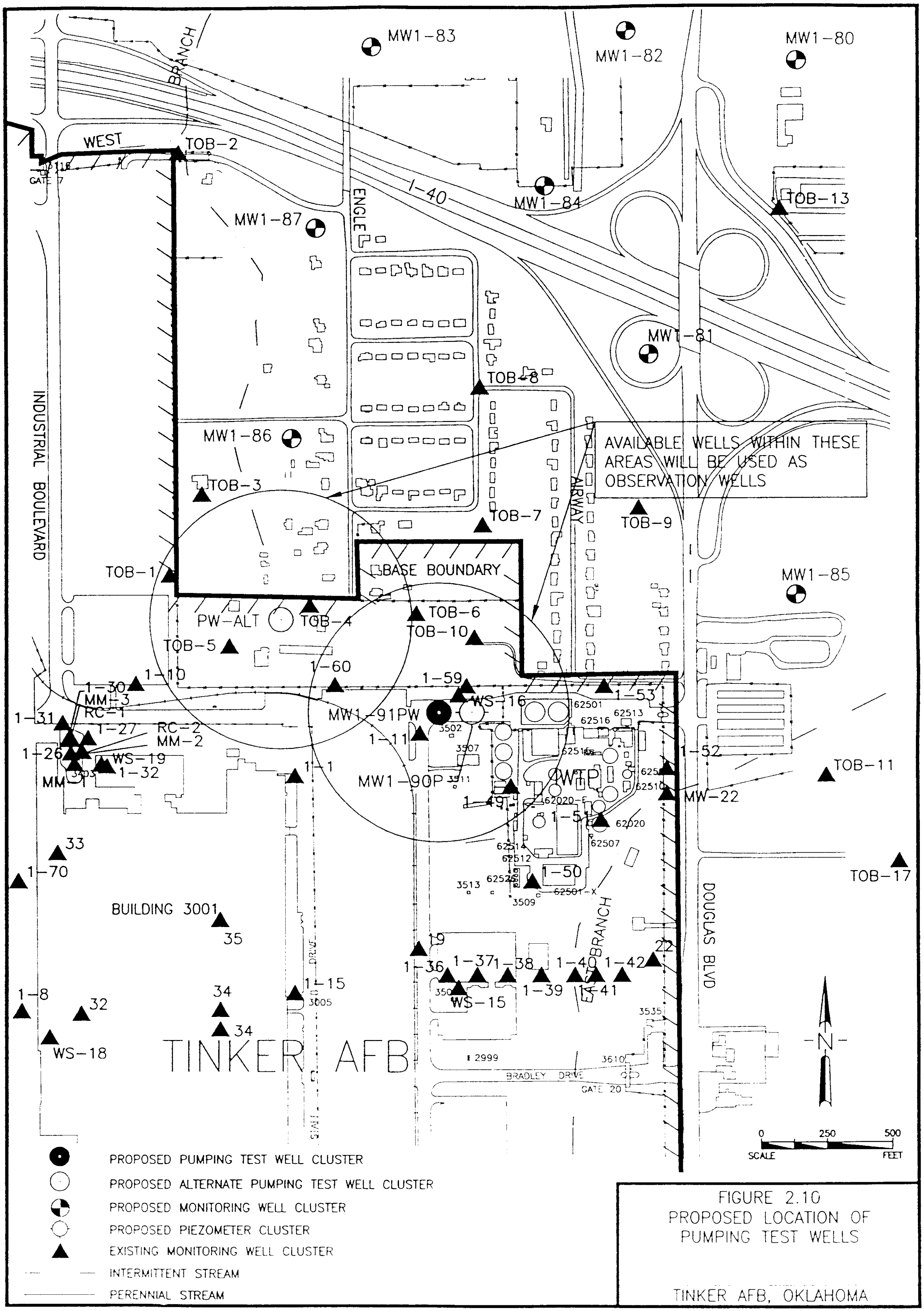

FIGURE 2.10
PROPOSED LOCATION OF
PUMPING TEST WELLS

TINKER AFB, OKLAHOMA

Geotechnical samples will be collected from the four deep continuous cores as described in Section 3.1.1, and each corehole and core will be geophysically logged as described in Section 2.6. Following completion of coring, the cores will be packaged and transported to the subcontracted laboratory, following ASTM D4220, "Practices for Preserving and Transporting Soil Samples," for the core GR logging, as described in Section 3.1.1. The cores will then be transported to the University of Oklahoma Core Library for storage. Core samples suspected to be hazardous based on field observations will not be shipped to the core library. The geophysical testing laboratory will be provided a drum for temporary storage of the samples suspected of being contaminated. This drum will then be taken to Tinker AFB for disposal in accordance with all applicable laws and regulations. The pilot holes will also be geophysically logged as described in Section 2.6.

To avoid cross-contamination of samples, all soil sampling equipment will be decontaminated before each use and between sampling locations. Decontamination procedures are described in Section 2.9.

2.4.1 Drilling Specifics

Any water used during the drilling, grouting, sealing, and equipment washing will be approved by Tinker AFB prior to the arrival of the drilling equipment on-site. Water sources will meet the requirements defined in the basic statement of work (Tinker AFB, 1993).

The type of air compressor and lubrication oil used will be recorded and a pint sample will be retained of each type and lot of oil , in the event of future problems. An air line filter will be used on the air line and will be changed per manufacturer's recommendations during operations or when oil is visibly detected in the filtered air. This maintenance will be recorded on the drilling log. Air usage will be fully described on the drilling log to include the information described in the basic statement of work (SOW) (Tinker AFB, 1993). The drilling log form is included in Section 6.

Guidelines concerning the use of additives during drilling procedures are described in the basic SOW (Tinker AFB, 1993). Additives, except for water, will not be used for dust control or cutting removal. Only antifreeze without rust inhibitors or sealants will be used. If antifreeze is added to any pump, hose, etc., in an area in contact with the drilling fluid, the antifreeze will be completely purged from the equipment prior to the equipment's use in drilling, grout mixing, or any part of the overall drilling operation. Only Teflon® tape, or other lubricants approved by regulatory agencies will be used on the threads of downhole drilling equipment. Commercial products such as Well Guard®, Pure Gold Lube®, and Green Stuff® are commonly used for drilling operations during monitoring well installation. U.S. EPA VI, Oklahoma Water Resources Board (OWRB), and Oklahoma Department of Environmental Quality (ODEQ) will be contacted for questions before any lubricant is used. Additives containing lead or copper shall not be used. The least amount of lubricant necessary shall be applied. These precautions shall preclude residual groundwater sample contamination caused by the lubrication of the downhole equipment (Tinker AFB, 1993).

The use of any bentonite will be approved by Tinker AFB prior to the arrival on-site of the drilling equipment. At least six working days will be allowed for approval. The written request will include:

- Brand name(s)
- Manufacturer(s)
- Manufacturer's address(es) and telephone number(s)
- Product description(s) from package label(s) and manufacturer's brochure(s)
- Intended use(s) for the product
- Name and phone number of approving State or Federal EPA representative.

All boreholes, coreholes, and pilot holes will be protected from surface runoff, e.g., precipitation, wasted or spilled drilling fluid, and miscellaneous spills and leaks. This will be achieved through use of starter casing, recirculation tanks, berms about the borehole, and surficial bentonite packs as appropriate.

2.4.2 Safety Measures

All exploratory well drilling and borehole operations will be monitored using an HNU® photoionization detector (PID) to detect the presence of volatile organic compounds (VOCs). In addition, the drill cuttings will be monitored for discoloration and odor. The HNu, which will be calibrated at least once daily according to the manufacturer's specifications, will be used as an indicator of the presence of significant organic vapor levels. Samples will be chosen for organic vapor headspace analysis based on instrument scanning and/or qualitative indications of contamination. A representative portion of each sampling interval will be placed in a glass jar for headspace analysis. The analysis will be conducted by securely placing aluminum foil over the top of the jar, setting the jar aside for 10 to 20 minutes at 70°F to 90°F to allow volatiles to escape from the soil sample, and then inserting the probe of the HNu through the foil to measure the level of VOCs in the headspace of the jar. Organic headspace analysis results will be recorded on the drilling log.

During drilling operations, headspace analyses will also be periodically conducted on drill cuttings. If soil cuttings are suspected to be hazardous (based on HNu measurements greater than 50 ppm, odors, or discoloration), they will be placed in proper containers and tested for toxicity characteristic leaching procedure (TCLP) volatile organics and metals, as outlined in Section 2.10. Containerized hazardous waste will be characterized and arrangements will be made for disposal. As described in Section 2.10, drums will be labeled in accordance with the Tinker AFB hazardous waste identification system.

2.4.3 Lithologic Descriptions

Lithologies will be described by a geologist using materials retrieved with a barrel sampler, cuttings during rotary drilling, or core samples. Lithology will be logged at 0.5-foot intervals and at each change of lithology.

Lithologic descriptions of unconsolidated material will consist of the predominant lithology in capital letters, followed by the predominant mineral content, secondary components and estimated percentage of sand, color, particle angularity, plasticity, significant structural or textural features, consistency (cohesive soil), density (non-cohesive soil), coherency, moisture content, and depositional environment and formation. Dimensions of the predominant and secondary particle sizes will be recorded using the metric system. Descriptions of clastic deposits will include symbols of the Unified Soil Classification System (ASTM D2487-85). Classification of color will follow Munsell® color charts.

Lithologic descriptions of consolidated materials will follow standard professional nomenclature. Special attention will be given to describing fractures, vugs, solution cavities and their fillings or coatings, and any other characteristics affecting permeability. Classification of color will follow Munsell color charts. A sample drilling log form is in Section 6. The vertical scale of the field logsheets will be appropriate for the level of detail noted.

The drilling log will also list the following information:

- Boring or well identification
- Purpose of boring (soil sampling, monitoring well)
- Location in relation to a landmark
- Name of drilling contractor
- Description of drilling equipment: rod size, bit type, pump type, rig manufacturer, model number
- Drilling method
- Name of overseeing geologist
- Types of drilling fluids and depths at which they were used
- Diameter of boring
- Depth at which saturated conditions were first encountered
- Depths of lithologic boundaries, in feet or fractions thereof
- Sample depths
- Zones of caving or heaving
- Depths at which drilling fluid was lost and amount lost
- Volume of drilling fluid used
- Changes in drilling fluid properties
- Drilling rate
- Any problems that are encountered during drilling.

Drilling logs will be composed directly in the field. The original drilling log (and diagram) will be submitted directly from the field to Tinker AFB within

3 working days after the boring is completed. In those cases where a monitoring well or other instrument is to be inserted into the boring, both the log for the boring and the installation diagram shall be submitted within three working days after the instrument is installed.

2.4.4 Abandonment Procedures

Coreholes and pilot holes will be abandoned to prevent migration of substances between geological formations or from the surface. The abandonment will be approved by Tinker AFB prior to any casing removal, sealing, or backfilling. All pilot holes and coreholes will be plugged as soon as possible after completion of use in a period not to exceed 3 days. Abandonment information will be included on the drilling log form. A sample of this log is in Section 6.

Once approved, the boring to be abandoned will be sealed by grouting from the bottom of the boring to ground surface. Grout will be pumped into the borehole until undiluted grout flows from the boring at ground surface. The grout will be mixed in the following proportions: 10 parts of neat Portland type I cement to ½ part by weight 100 percent sodium bentonite powder with approximately 7 gallons of approved water per 94-pound bag of Portland type I cement. The bentonite will be added after the required amount of cement is mixed with water. A mud balance will be used to determine the grout weight. This weight will be recorded on the drilling log. The weight should be between 13.2 and 14 pounds per gallon. Grout will be thoroughly mixed and free of lumps before placement. After 24 hours, the abandoned site will be checked for grout settlement. Any settlement depression shall be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at ground surface without any depressions.

A multi-purpose completion report will be completed and submitted to the OWRB, by the driller, within thirty days after completion and/or plugging of each monitoring well and corehole (OAC 785:35-7-2(a)(4)).

2.5 WELL CONSTRUCTION AND DEVELOPMENT

2.5.1 Well Construction

A total of thirty-nine wells are scheduled to be constructed during this investigation. This includes nine monitoring well clusters (MW1-79 through MW1-87), three piezometer clusters (MW1-88P through MW1-90P), and one pumping test well cluster (MW1-91PW). Twelve clusters, consisting of three wells each, will be installed at depths of approximately 40 feet, 90 feet and 150 feet bgl. The proposed locations of the well clusters are shown on Figure 2.9. The specific locations are outlined in Table 2.1. Three wells at approximately the same depths will be constructed for use in the aquifer pumping tests. All well installations will conform to state and local regulations, EPA's TEGD (EPA, 1986 and 1992), and the basic SOW (Tinker AFB, 1993).

The piezometers (MW1-88P A, B, C to MW1-90P A, B, C), and the pumping test wells (MW1-91PW A, B, C) will be installed following the same procedures for monitoring wells. The pumping test wells will be screened the entire saturated

Table 2.1 Proposed Well Locations
Tinker AFB SCGW RI/FS

Well Cluster	Location
SCGW-MW1-79	Northeast of the base; east of the intersection of Douglas Blvd. and I-40 near Soldier Creek.
SCGW-MW1-80	Northeast of base; northeast of the intersection of Douglas Blvd., and I-40; south of 29th Street.
SCGW-MW1-81	Northeast of base; at the intersection of Douglas Blvd., and I-40; inside southeast cloverleaf.
SCGW-MW1-82	Northeast of base; northwest of the intersection of Douglas Blvd., and I-40; just south of 29th Street.
SCGW-MW1-83	Northeast of base; northwest of the intersection of Douglas Blvd., and I-40; south of 29th Street.
SCGW-MW1-84	Northeast of base; just northwest of the intersection of Douglas Blvd., and I-40; south of 29th Street.
SCGW-MW1-85	Northeast of base; southeast of the intersection of Douglas Blvd., and I-40; west of existing well cluster TOB-20B.
SCGW-MW1-86	Northeast of base, North of TOB-4 and west of TOB-8 clusters.
SCGW-MW1-87	Northeast of the base; west of the intersection of Douglas Blvd., and I-40.
SCGW-MW1-88P	Northeast of the base; northeast of the intersection of Douglas Blvd. and 29th Street.
SCGW-MW1-89P	Northeast of the base; northwest of the intersection of Douglas Blvd. and 29th Street.
SCGW-MW1-90P	On base; northwest of IWTP; approximately 100 feet west of existing well cluster MW1-59.

thickness of the confined zones and at least the bottom two-thirds of the unconfined zone. The pumping test wells will be 6-inch outside diameter (OD) to accommodate a 4-inch (standard size) submersible pump with a shroud. The piezometers will be 2-inch diameter and will be completed with 5 feet of screen or less. The screen for each piezometer will be set in the center of the saturated zone for accurate measurement of the hydraulic head as an observation well.

The installation of each well will begin within 12 consecutive hours of boring completion. No breaks in the installation process will be made until the well has been grouted. Once begun, the procedure will not be interrupted due to the end of the workshift, darkness, weekend, or holiday. Exceptions will be requested in writing to Tinker AFB for approval prior to drilling. The request will include:

- Well(s) in question
- Circumstances
- Recommendations and alternatives

In case of unscheduled delays such as personnel injury, equipment breakdowns, sudden inclement weather, or scheduled delays such as borehole geophysical surveys, no approval is needed, but Tinker AFB will be notified. Installation will continue as soon as possible.

The 90-foot-deep wells will be double-cased and the 150-foot-deep wells will be triple-cased to prevent cross-contamination between the water-bearing zones. Each monitoring well will be constructed with 4-inch-diameter PVC casing and screen. Schedule 40 PVC will be used for the 40- and 90-foot-deep wells. Schedule 80 PVC will be used for the 150-foot-deep wells. The shallow wells (40-foot-deep) will be constructed with 15 feet of screen to allow for seasonal water level fluxuations. Between 5 and 10 feet of 0.010-inch wire wound screen will be used for the 90-foot and 150-foot-deep monitoring wells. The wells constructed for the pumping tests will be screened through the entire saturated zone of concern with 6-inch-diameter PVC. Six inches to one foot of sand pack is allowed below the screen. This length should be minimized to avoid any possibility of penetrating a lower confining unit below the screened interval. All connections will be flush-jointed and threaded. The well bottoms will be capped with a PVC cap or plug within 0.5 feet of the open portion of the screen. Casing will extend from the top of the screen to just below ground surface for flush-mount wells, or to approximately 2.5 feet above ground surface for aboveground wells. All screens, casings and fittings will be new. No glues, solvents, or thread compounds will be employed during screen and casing installations.

Well design will be based on the results from lithologic logging of the cores and the results of the borehole and pilot hole geophysical logs. ES will design the wells by the standards outlined in *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers* (ASTM, 1992) and in *Groundwater and Wells* (Driscoll, 1986). ES will also use Battelle's onsite experience in well design such as the interval to be screened and sand pack design.

A 10-20 mesh filter pack will be used to retain particles of the unconsolidated alluvium and loess. The filter pack material will be approved by Tinker AFB prior to installation. At least eight working hours will be allowed for the approval process. A one-pint representative sample will accompany the request for approval which will include a description of the sample in terms of:

- Lithology
- Grain size distribution
- Trade name
- Source, both company and origin
- Processing method
- Screen slot size.

For the three wells installed for the aquifer test, screen and sand pack sizing will be based on sieve analyses of the formation material. Samples for the sieve analyses will be collected during drilling of the pilot hole.

Single-Cased Wells

The shallowest well of each three well cluster will be approximately 40 feet deep and will be screened to monitor the perched saturated zone (USZ). These shallow wells will be single cased. The unconsolidated surface deposits will be augered with an 8.5-inch bit to a depth of approximately 40 feet. The pumping test well borehole will be drilled with a 10-inch bit. Schedule 40 PVC with 15 feet of 0.010-inch wire wound screen will be used for these shallow wells. The screen and casing will then be inserted into the borehole. The filter pack will be emplaced from the bottom of the borehole to a maximum of 3 feet above the screen slot by the tremie pipe method. The volume of filter pack used must equal the calculated volume for the appropriate length of well annulus. If the pack materials have bridged, measures such as surging the well must be taken to enhance settling of the filter material.

A 100 percent sodium bentonite seal will be placed above the sand pack to a minimum thickness of 5 feet to form an adequate seal above the pack materials. The bentonite seal will be wetted in the hole with potable water (when the seal is above the water table) to ensure that the seal is developed before grouting operations begin. A slurry seal will only be used as a last resort, and if used will be a thickness of less than 5 feet. Slurry seals require an extra 2 feet of fine-grained filter pack overlying the normal filter pack to prevent slurry invasion into the well.

Cement grout with bentonite gel will be placed from the top of the bentonite seal to 2 feet below ground surface. The grout will be mixed in the proportion described in Section 2.4.4. The grout will be placed in the annulus by the tremie pipe method, with the bottom of the tremie pipe set near the top of the bentonite seal. If necessary, grout will be added at the surface to compensate for settlement. The procedures for grouting outlined in Section 2.4.4 will be followed. Figures 2.11 and 2.12 illustrate typical monitoring well construction with single casing.

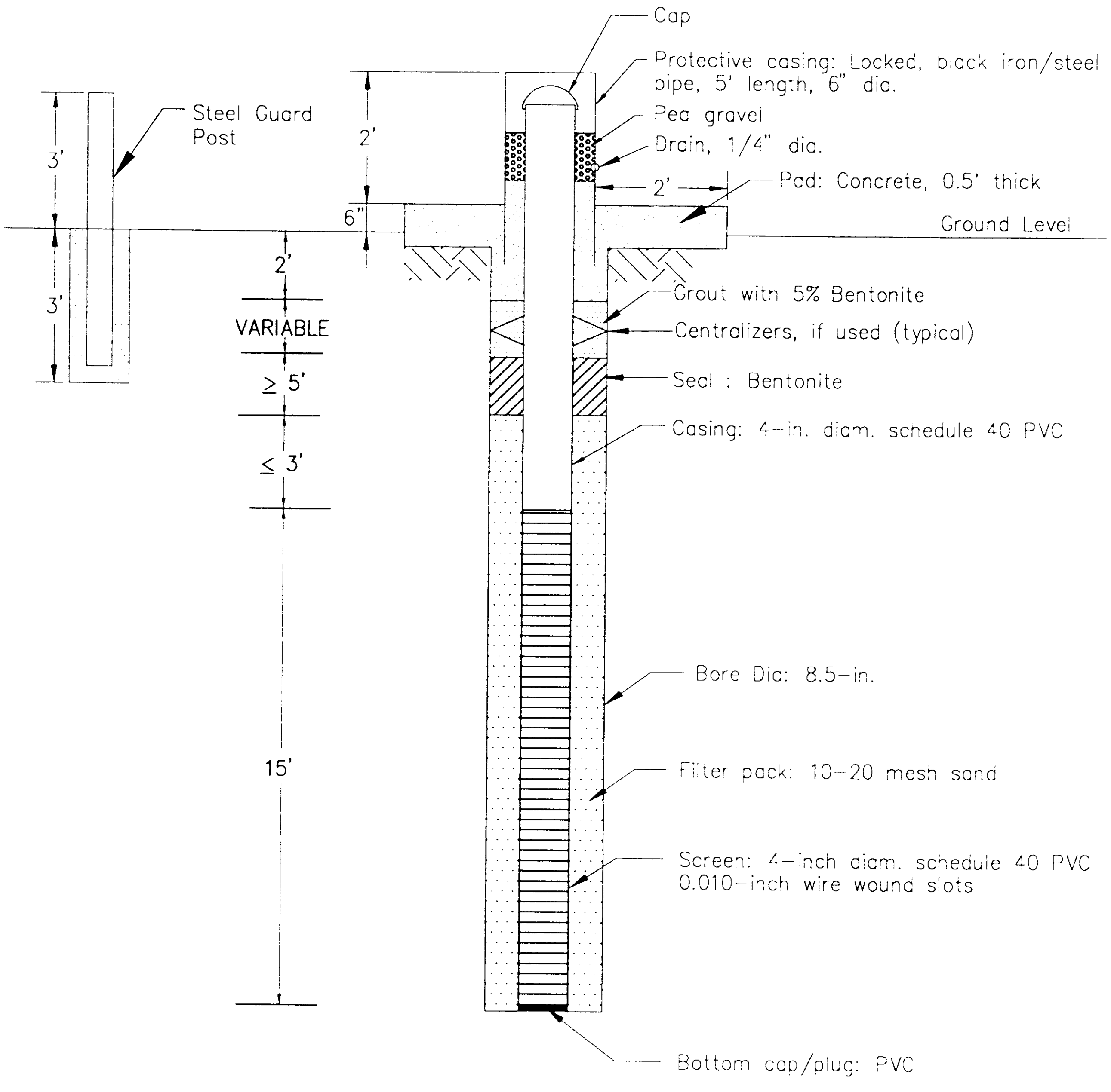

FIGURE 2.11
TYPICAL ABOVEGROUND MONITORING WELL COMPLETION

TINKER AFB, OKLAHOMA

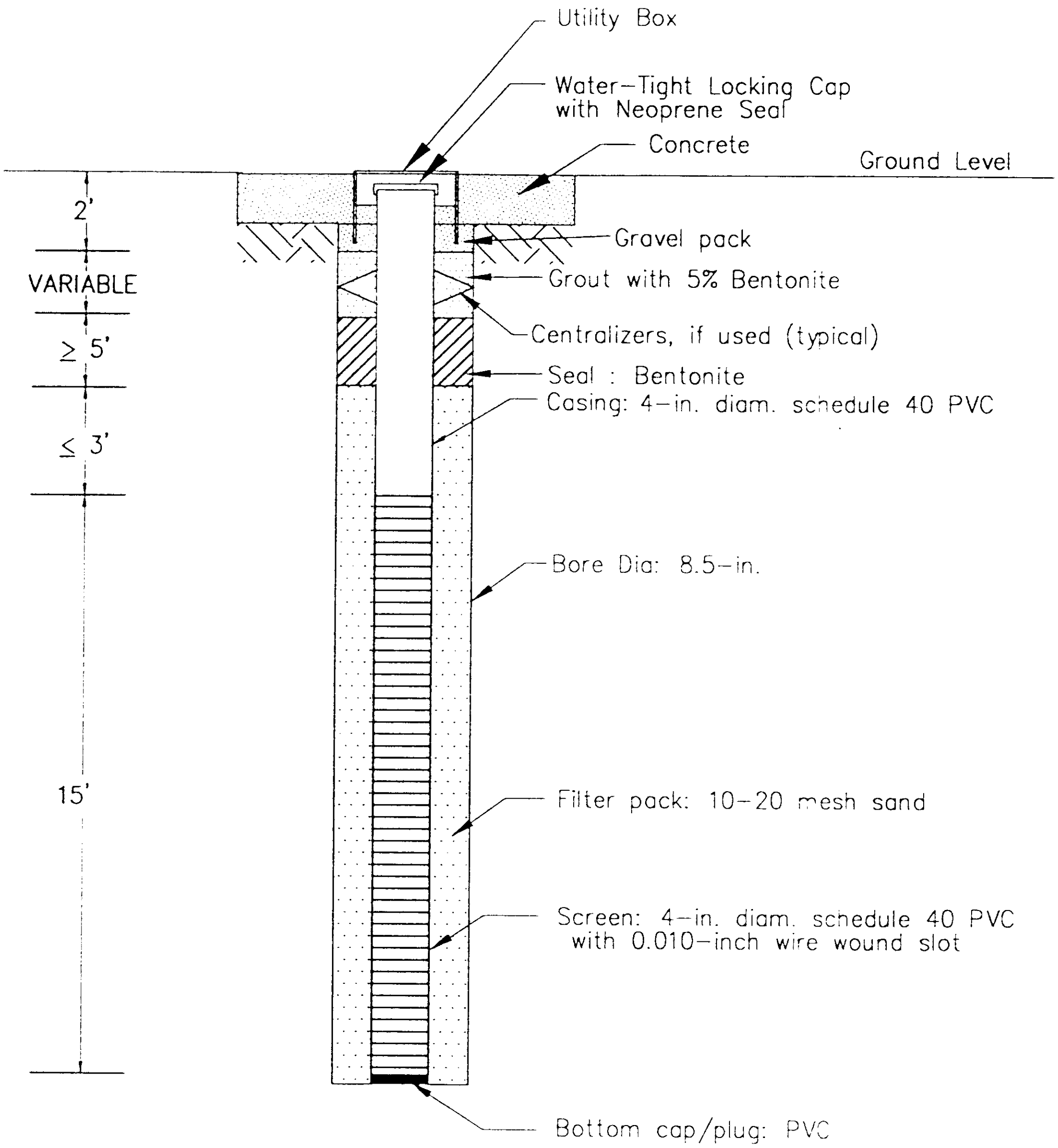

FIGURE 2.12
TYPICAL FLUSH
MONITORING WELL
COMPLETION

TINKER AFB, OKLAHOMA

Well centralizers, if used, will be made of PVC and attached to the casing via PVC or stainless steel. They will not be attached to the well screen or to that part of the well casing exposed to pack material.

Double-Cased Wells

Thirteen of the wells (including nine monitoring wells, three piezometers, and one aquifer pumping test well) will be double-cased. Figure 2.13 is an illustration of typical monitoring well construction with double casing. These wells will be drilled to approximately 90 feet and will be screened to monitor the upper portion of the lower saturated zone (LSZ).

An 8.5-inch hole will be drilled 2 to 3 feet into the top of the confining bed, approximately 40 feet bgl . A 14-inch hole opener will be rigged in the borehole to guide the drilling. A 14-inch borehole will then be drilled to the same depth. The borehole will be conditioned by circulating air or water without drilling until the hole is cleaned of cuttings and the mud has been displaced.

The surface casing will then be inserted into the borehole. The 10-inch outside-diameter (OD) surface casing will be sections of steel welded together for the total length. Centralizers will be welded on to the surface casing at 30- to 40-foot intervals. After the casing and centralizers have been emplaced, the annulus between the borehole and the casing will be filled with bentonite cement grout. The grout will be allowed to cure for at least 24 hours.

After the grout has cured, the drilling will continue with an 8.5-inch bit. The hole will be drilled a few feet deeper than required for well installation to allow for cavings during casing placement. The borehole will be conditioned by circulating air or water until the cuttings have been removed. After the tool string has been removed from the hole, the total depth will be checked with a weighted surveyor's tape.

The well casing and screen will be inserted into the borehole in manageable segments. Any excess borehole greater than 1 foot below the screen (assuming no sump) will be backfilled with bentonite prior to setting the screen and riser. Centralizers will be placed at 30- to 40-foot intervals, but none will be located within the screen and filter pack zone. Before sand packing and cement grouting of the annulus, the casing string will be suspended and will not be allowed to sit on the bottom of the hole because the weight of the casing may reduce the slot size or collapse the screen.

The filter pack will be placed by tremie pipe starting at a location near the bottom of the screen. The tremie pipe will be slowly withdrawn so that the filter pack is placed evenly around the screen without bridging and without separation of the sand grains due to gravity in the long water column. Six inches or more of filter pack material will be emplaced under the screen, and the filter pack will extend 2 to 3 feet above the top of the screen in each well.

A bentonite seal at least 5 feet thick will be placed by a tremie pipe onto the top of the filter pack. The bentonite cement grout will be tremied into the annulus to within 2 feet of the surface.

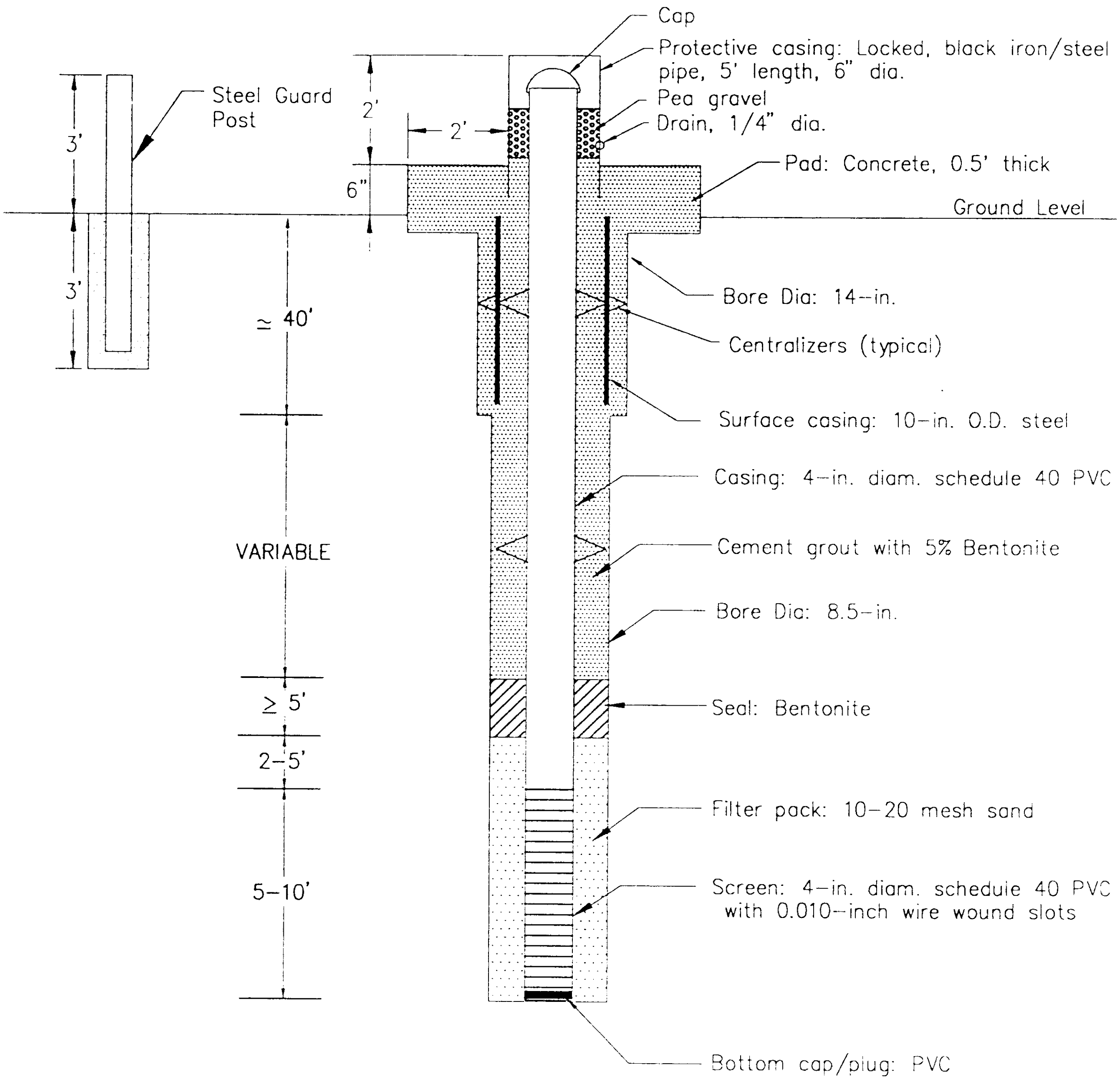

FIGURE 2.13
TYPICAL DOUBLE-CASED MONITORING WELL COMPLETION

TINKER AFB, OKLAHOMA

Triple-Cased Wells

Thirteen of the wells (including twelve monitoring wells and one aquifer pumping test well) will be triple-cased. These wells will be drilled to approximately 150 feet bgl and will be screened to monitor the lower portion of the LSZ. The construction of these wells will generally follow the procedures described for a double-cased well. Figure 2.14 illustrates a triple-cased well. An 8.5-inch hole will be drilled 2 to 3 feet into the top of the confining bed at a depth of approximately 40 feet. A 20-inch hole opener will be rigged in the borehole to guide the drilling. A 20-inch borehole will then be drilled to the same depth. The same procedures as described above for the surface casing of a double-cased well will be followed, with the exception that the surface casing of the triple-cased wells will be 16-inch OD. Again, the grout will be allowed to cure for at least 24 hours.

After the grout has cured, the drilling will continue with an 8.5-inch hole down to approximately 100 feet, until the drill bit is approximately 2 to 3 feet into the next confining layer. A 14-inch hole opener will be rigged in the borehole to guide the drilling. Ten-inch OD steel casing will be used to seal off the upper portion of the lower water-bearing zone. This casing will be inserted inside of the 16-inch OD surface casing. Grout will be pumped into the annulus via tremie. Again, the grout will be allowed to cure for at least 24 hours.

After the grout has cured, the drilling will continue with an 8.5-inch bit. The well casing and screen will be inserted into the borehole and the well will be completed as described above.

Surface Completions

Surface completion requirements are described in the basic SOW (Tinker AFB, 1993). Figures 2.11 and 2.12 illustrate typical aboveground and flush-mount monitoring well completions.

Aboveground wells will be provided with a loose fitting telescopic cap to keep precipitation out of the casing. A 5-foot minimum length of new, black iron and steel pipe extending about 2.5 feet above ground surface will be set in the grout. The distance between the top of the well casing and the top of the protective casing will be no greater than 3.6 inches. The diameter of the protective casing will be 6 inches. An internal mortar collar will be placed within the well-protective casing annulus from ground surface to 0.5 foot above ground surface with a ¼-inch-diameter hole (drainage port) in the protective casing centered $^{1}/_{8}$-inch above this level. The mortar mix will be (by weight) 1 part cement to 2 parts sand (the filter pack), with minimal water for placement. This must be completed at least 48 hours prior to well development. Pea gravel will be put inside the protective casing from the top of the mortar collar to below the top of the casing to ease tool retrieval and to prevent small animals/insects from entering through the drain. Four 4-inch-diameter, 6-foot-long steel guard posts, which are filled with concrete, will be placed 2 feet radially around the protective casing outside of the concrete surface pad. They will be placed about 3 feet bgl and will rise a minimum of 3 feet above ground surface. The surface pad will slope away from the well, be approximately 0.5 foot thick, and extend 2 feet radially from the protective casing.

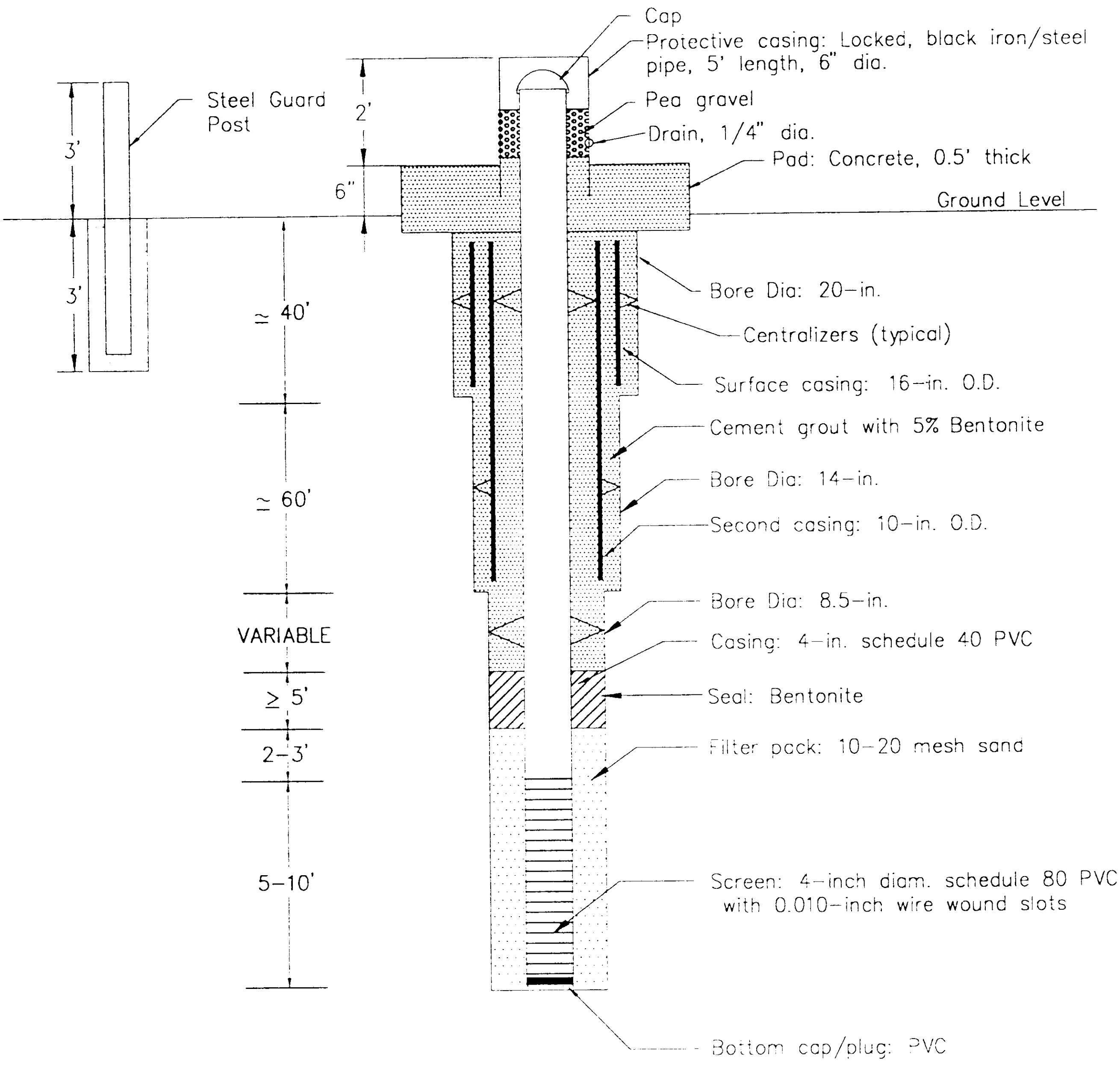

FIGURE 2.14
TYPICAL TRIPLE-CASED MONITORING WELL COMPLETION

TINKER AFB, OKLAHOMA

The surface pad will be constructed prior to development. The identity of the well will be marked on the casing cap and the protective casing. The protective casing will be painted fluorescent orange with a paint brush after installation and prior to development.

Flush-mount wells will be constructed in parking and traffic areas. In these cases, the casing will be cut about 3 inches below ground level and will be sealed with a watertight cap. A freely draining valve box with a locking cover will be placed over the casing. The top of the casing will be at least 1 foot above the bottom of the box. The valve box lid will be centered in a 3-foot-diameter, 4-inch-thick concrete pad that slopes away from the box.

A rounded brass monument will be placed on each monitoring well concrete pad to serve as a permanent benchmark. All wells will be secured as soon as possible after drilling with corrosion-resistant locks. The locks will all be keyed the same as the existing monitoring well locks, and the key will be provided to Tinker AFB following completion of the field effort.

Well Completion Form

A well completion form will be completed for each monitoring well. The information recorded on the form will be logged into the Installation Restoration Program Information Management System (IRPIMS) software as soon as possible after the well has been completed. The form will include the following information:

- Well location
- Well identification
- Installation date(s)
- Overseeing geologist
- Elevation of ground surface and of the measuring point notch at the top of the casing
- Diameter of surface casing, casing type, and methods of installation
- Annular diameter of borehole for casing sets
- Borehole diameter of production liner
- Total boring depth
- Lengths and descriptions of screen and casing
- Lengths and descriptions of the filter pack, bentonite seal, casing grout, and any backfilled material
- Volume of filter pack used
- Volume of bentonite used for seal
- Volume of grout used
- Coupling/joint design and composition
- Centralizer placement

- Drainage port location and size
- Internal mortar collar location
- Protective casing composition and nominal inside diameter
- Any use of solvents, glues, and cleaners to include manufacturer and type
- Steel post configuration
- Centralizer design and composition
- Elevation of water level before and immediately after development.

The original well diagram will be submitted within three working days after well installation has been completed. Within 3 working days of surface completion, a copy of the original well diagram which includes the surface completion information will be submitted to Tinker AFB.

2.5.2 Monitoring Well Development

Monitoring wells will be developed as soon as possible but no sooner than 48 hours after internal mortar collar placement has been completed. All fluids used during well construction will be removed during development. Development will be accomplished with a pump and will be supplemented with a bottom discharge and filling PVC bailer (for sediment removal) (EPA, 1992). Clean nylon rope will be used to raise and lower the bailer. Before well development begins, the water level will be measured within 0.01 foot using a graduated water level indicator with respect to a reference point permanently marked on the north side of the top of the casing.

During development, water will be removed throughout the entire water column by periodically lowering and raising the pump intake. Well development will continue until the following conditions are met:

- A minimum removal of five well bore (or pore) volumes of water. The shallower wells may require in excess of 10 pore volumes to reduce turbidity. However, the turbidity of the perched wells may never be reduced enough to obtain clarity.
- The well water is clear to the unaided eye.
- The sediment thickness remaining within the well is less than 5 percent of the screen length.

The well bore (or pore) volume is defined as the volume of submerged casing, screen and filter pack (assuming a 30 percent porosity). If recharge rates are slow and the required volume cannot be removed in 48 consecutive hours or the water remains discolored or excess sediment remains, Tinker AFB will be contacted for guidance. A minimum of five additional pore volumes will be removed when excess sediment remains.

Specific conductance, pH, and turbidity measurements will be taken once before, twice during, and once after development. These measurements will be recorded on the development logs. If pH and conductivity stabilize during the removal of the final two pore volumes, and the turbidity of the water is less than five nephelometric turbidity units (NTUs), the well will be considered to be developed. If pH and conductivity do not stabilize after 40 pore volumes have been removed, but the turbidity of the water is less than 5 NTUs, the well will be considered to be developed. If excess sediment remains, the well will not be considered as developed and the well will not be sampled. At this point, an evaluation of the well's integrity will be made. The pH, conductivity, and turbidity meters will be calibrated daily. Calibration procedures are further described in Section 4.4.

A one-pint sample of the last water to be removed during development of each well will be obtained and kept on-site, under non-freezing conditions, for visual inspection. Development will be completed at least 14 days before well sampling.

Development water that is deemed nonhazardous based on field observations and existing information on the level of contamination at the site will be pumped into roll-off bins or drums for later discharging at the oil-water separator at the IWTP. Water suspected to be hazardous will be disposed in accordance with all applicable laws and regulations.

Well development will include the washing of the entire well cap and the interior of the well casing above the water table using water from that well, before and/or during development.

Well development data recorded on the well development logs include:

- Volume of water removed from the well
- Measurements of pH, conductivity, and turbidity
- Static water level from top of casing before and 24 consecutive hours after development has been completed
- Volume of water in well and in saturated annulus prior to development
- Type and size/capacity of pump and/or bailer used
- Description of surge techniques, if used.

These logs will be submitted to Tinker AFB within three working days after development has been completed.

Water removed from a well during development will not be counted towards any pre-sample purging requirements.

2.6 GEOPHYSICAL LOGGING

During the private well survey, twelve wells will be geophysically logged using GR and CAL tools. The logging will be performed using a pickup-size truck with a hoist mounted on the back. The geophysical log will be printed out immediately on site using the subcontractor's computer.

Borehole geophysical logging will be performed inside each of the four deep coreholes. Seven geophysical logs will be used: GR, CAL, spontaneous potential (SP), resistivity (R), micro-resistivity (MR), density (D), and neutron (N) logs.

Borehole geophysical logging will also be performed inside each of the thirteen pilot holes for the well clusters. Four geophysical logs will be used: GR, CAL, SP, and R.

All of the logs will be digitally recorded over the entire depth. A scale of 10 feet to the inch of well depth will be used to print the geophysical logs. All logged curves, log scales, land surface, bottom of hole, and logged interval will be clearly marked on each log. Final prints will have a heading showing all pertinent information, including, but not limited to, the date of logging, point where tool is zeroed (usually ground surface), tool number, logging company, operator name, well location (¼ section, ½ section, section, township, and range) and a comment section describing unusual field occurrences or other information that may aid in the interpretation of the geophysical logs. Logs will be submitted within 10 working days after the completion of the geophysical logging.

In addition, a GR log will be run on each continuous core at the subcontracted geotechnical engineering laboratory to ensure correlation of the core to the subsurface formation.

2.7 AQUIFER TESTS

Three long term aquifer pumping tests will be performed in the area of investigation to determine aquifer parameters for the conceptual model for Tinker AFB. The tests will be performed on three aquifer zones at approximate depths of 40 feet, 90 feet, and 150 feet. Each well in the pumping test well cluster will be constructed with 6-inch-diameter PVC. These wells will be screened across the entire saturated zone of concern to enhance recovery. The proposed locations of the pumping test wells are shown on Figure 2.10. If the alternate pumping test location is used, piezometer cluster MW1-90P will be moved also.

Several calculations were made to estimate the USZs and LSZs response to pumping. Based on these calculations, the optimum pumping rate, well design, observation well locations, and the pumping test well location were chosen. These calculations were made following procedures described in *Groundwater and Wells* (Driscoll, 1986). Table 2.2 shows the pumping test design parameters.

The Cooper and Jacob (1946) method, based on the Theis equation, was used to estimate the drawdown during the pumping test. The Cooper and Jacob method was developed for confined aquifers. Since the USZ and LSZ are unconfined in the area proposed for the test, the values obtained using this method can only be considered as a rough estimate. However, for the purpose of determining the optimum pumping rate and the resultant radius of influence, these results provide adequate estimations.

The wells will be screened across the total thickness of the unit being tested. Each of the three aquifer tests will be conducted in the same manner. One piezometer cluster (MW1-90P) installed in Task 5, any other wells deemed appropriate in Task 2, and existing monitoring wells will be selected as observation wells (OW). The proposed location of the pumping test well cluster and an alternate location is shown in Figure 2.10. The alternate location will be used if the

Table 2.2
Pumping Test Design Parameters

Assumptions

Zones	Saturated[1] Thickness	Storativity[2]	Hydraulic[3] Conductivity	Transmissivity
USZ	18 feet	0.10	1.96 x 10 -3 ft/min	380 gpd/ft
LSZ1	36 feet	0.10	1.47 x 10 -3 ft/min	570 gpd/ft
LSZ2	45 feet	0.0001	5.9 x 10 -4 ft/min	285 gpd/ft

Design

Zones	Optimum Pumping Rate	Radius[4] of Influence	Drawdown at[5] 1 foot from Pumping Well	Screen Length	Total Gallons Pumped
USZ	5 gpm	90 feet	13 feet	Bottom 15 feet of saturated zone	50,400
LSZ1	15 gpm	120 feet	26 feet	Bottom 30 feet of saturated zone	151,200
LSZ2	10 gpm	2,200 feet	50 feet	45 feet	100,800
				Total	302,400

1. USACE, 1991
2. Driscoll, 1986
3. USACE, 1988a
4. Radius of influence at the end of the 7 day test
5. Drawdown at the end of the 7 day test

proposed location is not accessible. The piezometers and monitoring wells that will be used as observation wells for the pumping tests are also shown on Figure 2.10. Criteria for selecting the proposed and alternate pumping test locations are:

- The pumping well cluster will be located in or close to the focus RI/FS area, close to Tinker AFB plume
- Space which is safe from trespassers and near the pumping test location is needed for emplacement of generator and at least two 50,000-gallon (or larger) water tanks
- The location shall be close to IWTP or close to the base sewer to minimize the transport distance of discharge water
- The location will maximize the use of existing monitoring wells as observation wells to describe anisotropic hydraulic conductivity
- The location will be outside of the base water supply well influence.

Each of the three pumping test wells will be constructed of 6-inch PVC casing and screen following the well construction procedures outlined in Section 2.5. The 6-inch diameter was selected to accommodate the pump and a pump shroud. To maximize the stress on the aquifer (i.e., maximum drawdown), the pump will be set near the bottom of the screened interval. A pump shroud will direct the groundwater flow into the pump over the pump motor. This will prevent the pump motor from overheating during the 7 day test.

Each of the three aquifer pumping tests will be performed in the same manner. Wells located near the pumping test wells will be used for observation wells (OWs). Table 2.2 lists the radii of influence for each zone. Wells located within or near that radius will be used as observation wells. The perched system (40 feet zone) will be tested first, the upper portion of the LSZ (90-foot zone) second, and the lower portion of the LSZ (150-foot zone) will be tested last.

Prior to each test, the water levels from the OWs that will be used for the test will be monitored for approximately 1 week prior to the test to establish water level trends. Following the water level trend analysis a step drawdown test will be conducted to determine the optimum pumping rate for the test. The step drawdown test will take approximately 1 day to complete. Once the aquifer has recovered from the step drawdown test, the constant discharge test will commence. All equipment that goes into the pumping well and the OWs will be decontaminated using the procedures described in Section 2.9.

Each test will consist of 7 days of continuous pumping. At least two 50,000-gallon (or larger) tanks will be used to containerize the water from the constant discharge test as well as the step drawdown test. Provisions will be made to transfer excess water to other holding tanks (to be located at the IWTP) as necessary. A direct reading flow meter with totalizer accurate to 1 gallon will be used to measure the pumping rate. The pumping rate will also be verified with a known volume container and stop watch.

During the test, the water in the pumping well and the OWs will be measured for their response to pumping. All three zones will be monitored to check for confining bed leakage. An eight channel data logger will be used to obtain continuous water levels during the test from the pumping well, the remaining two wells at the pumping well cluster, and three OWs (one screened in each zone). In addition to the eight channel data logger and pressure transducers, two well sentinel data loggers will be used to monitor OWs that are within the radius of influence of the pumping well, but are either located too far from the pumping well or in locations where transducer cables can not be run. Manual water level measurements will also be taken using an electric water level indicator to back up the data logger.

Once the constant discharge is complete, the recovery of the aquifer from the test well will be monitored for 1 to 2 days or until the water level returns to 95 percent of the static level prior to pumping. During the test and during the period immediately following the test, the discharge water will be sampled as described in Section 3.1.5. Samples will be collected to characterize the water for disposal. Disposal of IDW is described in Section 2.10.

Data from the pumping tests will be submitted within 10 days after the completion of the tests.

2.8 SURVEYING

Survey activities will be conducted by a licensed surveyor contracted by ES. Map coordinates will be determined by using a Universal Transverse Mercator (UTM), State Planar, or latitude and longitude grid to establish horizontal control to within ±1 foot (±0.3 meter). The ground surface and the measuring notch at the top of the well casing for each bore or well site will be surveyed to establish vertical control to within ±0.01 foot (±0.3 centimeters) using the National Geodetic Vertical Datum (NGVD) of 1983. All surveying will be coordinated with Tinker AFB Civil Engineering.

The x-coordinate will be the east-west axis, the y-coordinate will be the north-south axis. The reference location will be the origin. All elevation measurements will be referenced to NGVD.

All survey field data will be submitted to Tinker AFB. This submission will include the coordinates (and system) and elevation (ground surface and top of well casing) for all borings, wells, and reference marks. All permanent and semipermanent reference marks used for horizontal and vertical control (bench marks, caps, plates, chiseled cuts, rail spikes, etc.) will be described in terms of their name, character, and physical location.

2.9 EQUIPMENT DECONTAMINATION

To prevent sample contamination from the onsite sampling equipment and machinery, decontamination will be conducted using the following procedures.

A decontamination pad that is large enough to fully contain the equipment to be cleaned will be set up. One or more layers of heavy plastic sheeting will be used to cover the ground surface. Sampling equipment that comes into direct contact with samples will not be allowed to come in contact with the plastic.

Drill rigs, drill pipe, and other equipment that does not come into contact with the sample medium will be decontaminated with a steam cleaner before initial use and after each borehole is completed. Drill bits will be decontaminated with a steam cleaner prior to use at each boring or monitoring well location. If the hot water cleaning alone is found to be ineffective, the equipment may be scrubbed with laboratory-grade detergent, then rinsed with high-pressure steam. All visible dirt, grime, grease, oil, loose paint, etc., will be scrubbed until it has been removed. When possible, drilling will proceed from the "least" to the "most" contaminated sites.

The casing, centralizers, and screen will either be certified clean by the manufacturers or will be decontaminated by steam cleaning.

Sampling equipment that comes in direct contact with the samples will receive additional cleaning. This equipment includes continuous-core samplers, hand trowels, and bailers. Decontamination of the sampling equipment will consist of the following steps:

1. Clean with brush in a solution of laboratory-grade nonphosphate detergent (Alconox) in potable water.
2. Rinse with potable water.
3. Rinse with 10 percent nitric acid (for metals samples only).
4. Rinse with type II reagent-grade water (not general distilled or deionized water).
5. Rinse with pesticide-grade methanol.
6. Allow to air dry.
7. Wrap in oil-free aluminum foil if not used immediately. Sampling equipment used to collect samples for organic analyses can not come in contact with any type of plastic (e.g., plastic storage bags).

Purge and development equipment such as pumps will be decontaminated by flushing or pumping laboratory-grade detergent solution, potable water, then Type II reagent-grade water through the internal components (in the order listed). The exterior of the pump inlet hose will be steam cleaned. Pumping test equipment such as transducers will be decontaminated with detergent solution, potable water, and Type II reagent-grade water (in the order listed).

Based on field observations during the use of the equipment and existing information on the level of contamination at the site, all decontamination fluid that is deemed nonhazardous will be disposed of, along with other nonhazardous investigation-derived water, at the oil-water separator at the IWTP. Permission to dispose of water at the IWTP will be obtained from the plant manager to avoid violation of Tinker's NPDES permit. Approval will be sought each day (or as directed by the plant manager) that fluids may be disposed at the IWTP. Decontamination fluids that are suspected to be hazardous will be disposed in accordance with all applicable laws and regulations. ES will arrange for disposal of waste materials and fluids which cannot be treated at the IWTP.

Methanol and type II reagent-grade water will be purchased, stored, and dispensed only in clearly labeled glass or Teflon containers with Teflon caps or cap liners.

2.10 INVESTIGATION-DERIVED WASTE HANDLING

Management of Investigation-Derived Wastes During Site Inspections (EPA, 1991) will be used as a guidance for waste disposal methods during this project.

Soil cuttings from off-site drilling activities are not anticipated to be contaminated because of their distance from the hazardous source. Historical investigations also show that off-site locations have either low or no contamination. These and other soil cuttings considered clean based on site knowledge, visual inspection, and PID readings will be stored in a transportable roller-type dumpster for composite sampling and eventual appropriate disposal. Wastes will be separated in roll-offs by well cluster group. One composite sample will be collected from each well cluster group. However, if the amount of cuttings that will be generated at a location (specifically core locations) is expected to be too small to warrant use of a roll-off dumpster, drums will be used instead. All waste will be characterized by TCLP analyses.

A small quantity of drums containing suspected hazardous waste may also be generated during drilling. Soil cuttings suspected to be hazardous based on site knowledge, field observations, and PID readings will be placed in clean 55-gallon U.S. Department of Transportation (DOT) drums. Composite samples will be collected from drums of the same boring or location. Each sample will be composited from a maximum of ten drums. As many samples as are necessary to represent the total volume of potentially contaminated soil cuttings will be collected. Results from these analyses will dictate the disposal method. All wastes deemed hazardous will be transported and disposed at a permitted hazardous waste disposal facility. All nonhazardous solid waste will be disposed of at a nonhazardous waste landfill.

All development, purging, and decontamination waters are anticipated to be nonhazardous. These waters, along with other nonhazardous investigation-derived water will be disposed of at the IWTP oil-water separator after approval has been obtained from the plant manager each day (or as directed) that fluids may be disposed at the IWTP. If fluids are suspected to be hazardous based on field observation and existing information on the level of contamination at the site, they will be containerized, tested, and labelled for disposal as hazardous waste. ES will arrange for disposal of waste materials and fluids which cannot be treated at the IWTP.

Personal protective equipment (PPE) and disposable sampling equipment that is suspected to be hazardous will also be disposed in accordance with all applicable laws and regulations.

According to the RI/FS WP, approximately 316,800 gallons of water will be generated during the aquifer pumping tests and step drawdown tests. This will be temporarily stored in at least two 50,000-gallon (or larger) tanks as described in Section 2.7. These tanks will be sampled for characterization prior to disposal. Results will be received in 24 to 48 hours. If the tank contents are found to be nonhazardous, the water will be discharged to the oil-water separator at the IWTP or the GWTP, upon approval from Tinker AFB. If the tank contents are found to be hazardous, the tank may be stored at the point of generation for no more than 90 days. In addition, after all of the pumping tests have been completed, the water storage tank liner and underlying geotextile will be disposed of via an appropriate facility (see Section 5.1.12 of the WP).

2.11 SUMMARY OF FIELD ACTIVITIES

Table 2.3 is a summary of the type and number of field activities to be conducted at each site. Table 2.1 describes the proposed monitoring well locations. During the field activities, a number of deliverables will be required within a specific time frame. These deliverables and their time constraints are listed in Table 2.4. Approval is also required for a number of activities and media. Table 2.5 is a summary of these approval needs.

Table 2.3
Summary of Field Activities
Tinker AFB SCGW RI/FS

Task	Number of Groundwater/ Water Samples*	Number of Soil Samples*	Number of Sediment Samples*	Downhole Geophysical Logs	Monitoring Well Footage (ft)	Soil Boring/Pilot Hole Footage (ft)
Task 1 Historical review and windshield survey						
Task 2 Inspection of private wells	12			20 x 100′		
Task 3 Soldier Creek streamflow survey						
Task 4 Lithologic coring		24		4 x 200′		800
Task 5 Monitoring well construction and sampling	36			12 x 180′	3,360	2,160
Task 6 Conceptual model						
Task 7 Aquifer tests	3			1 x 150	280	150
Task 8 Soil sampling		48				100
Task 9 Sediment sampling			100			
Task 10 Sample analyses**						
Totals	51	72	100	4,540	3,640	3,210

* Does not include QA/QC samples.

** Analyses have been included in Tasks 1-9.

Table 2.4 Required Deliverables During Field Activities
Tinker AFB SCGW RI/FS

Required Deliverables	Time Deadline	Section Outlining Deliverables
Stream flow data	10 working days after completion of Task 3	2.3
Drilling logs	3 working days after completion of boring	2.4.1
One-pint sample of air compressor and lubrication oil	NA	2.4.1
Type II reagent-grade water chemical data	NA	2.5, 2.9
Original well diagrams	3 working days after well installation	2.5.1
Well diagram with surface completion	3 working days after completion of surface completion	2.5.1
One-pint sample of the filter pack material	Will accompany the request for filter pack approval	2.5.1
Well development logs	3 working days after development is complete	2.5.2
One-pint sample of last development water removed from each well	Will be kept on site for visual inspection	2.5.2
Geophysical logs	10 working days after completion of logging	2.6
Pumping test data	10 working days after completion of Task 7	2.7
Survey field data	NA	2.8

NA = no deadline is given in the basic SOW (Tinker AFB, 1993).

Table 2.5 Approval Needs During Field Activities
Tinker AFB SCGW RI/FS

Items Which Need Approval	Time Needed for Approval	Section Outlining Approval
Water source	No time limit; needs to be approved before use	2.4.1
Bentonite	6 working days	2.4.1
Boring/well abandonment	May request by telephone; written request needed within 5 working days	2.4.4
Break in monitoring well construction	NA	2.5.1
Filter pack	8 working hours	2.5.1

NA = no deadline for approval is given in the basic SOW (Tinker AFB, 1993).

SECTION 3

ENVIRONMENTAL MEDIA SAMPLING

An estimated fifty-one groundwater and seventy-two soil samples will be collected during this investigation. In addition, quality control samples, including trip blanks, ambient condition blanks, equipment blanks, and duplicates will be collected.

3.1 PROCEDURES

Procedures and practices used to collect, handle, and analyze samples will fulfill requirements of the basic SOW (Tinker AFB, 1993).

To avoid cross-contamination of samples, all soil sampling equipment will be decontaminated before each use and between sampling locations. Decontamination procedures are described in Section 2.9.

3.1.1 Core Sampling

Continuous core samples for gamma ray (GR) logging will be collected from the 200-foot-deep boreholes. A total of twenty-four samples will be collected from the four boreholes for geotechnical analyses. Lithologic logging is described in Section 2.4.3.

The continuous core samples will be collected in the following manner. After air or water has been circulated in the hole to remove as many cuttings as possible, the string of drill pipe will be removed from the hole. The core barrel will then be attached to the drill string and run into the hole. The core barrel will be used to obtain a representative in-situ sample.

The ES on-site geologist will collect the 24 samples for geotechnical analyses. The depth intervals of these samples will be chosen based on changes in lithology. These samples will be analyzed for Atterberg limits (ASTM D4318), soil moisture (ASTM D2216), permeability (ASTM D2434), particle size distribution (ASTM D422), and organic content (ASTM 2974). Undisturbed samples are required to achieve the most accurate results for geotechnical analyses. Therefore, special care will be taken in all sampling, handling, packaging, and shipping of these samples. Samples must be wrapped in plastic and sealed with Teflon tape or wax. Sample volume and preservation requirements and holding times are listed on Table 3.1.

The sample will be labelled with the project number, project name, date of sampling, core number, interval of sampling, and any other pertinent information. In addition, the sample will be marked "TOP" and "BOTTOM" so that the

Table 3.1 Sample Containers, Preservatives, and Holding Times for Soil Samples
Tinker AFB SCGW RI/FS

Parameters	Method	Sample Container	Preservative	Holding Time
Volatile organic compounds	SW-8260	One 4-ounce widemouth glass jar with Teflon-lined lid	Cool to 4°C	14 days
Semivolatile organic compounds	SW-3050/ SW-8270	One 8-ounce widemouth glass jar with Teflon-lined lid	Cool to 4°C	Extract within 14 days of collection, and analyze within 40 days of extraction
Total ICP metals[1] (recoverable)	SW-3050/SW-6010	One 8-ounce glass widemouth jar	Cool to 4°C	180 days
Total lead (recoverable)	SW-3050/SW-7421	One 8-ounce glass widemouth jar[2]	Cool to 4°C	180 days
Total arsenic (recoverable)	SW-3050/SW-7060	One 8-ounce glass widemouth jar[2]	Cool to 4°C	180 days
Total mercury (recoverable)	SW-7471	One 8-ounce glass widemouth jar[2]	Cool to 4°C	28 days
Total selenium (recoverable)	SW-3050/SW-7740	One 8-ounce glass widemouth jar[2]	Cool to 4°C	180 days
Chromium (VI)	SW-7195-SW-7198[3]	One 4-ounce glass jar	Cool to 4°C	24 hours
Cation exchange capacity	SW-9080			
pH	SW-9045			
Total organic carbon	SW-9060	One 4-ounce glass jar	Cool to 4°C	28 days
Geotechnical samples				
Atterberg limits	ASTM D4318	One to two feet of undisturbed core sample, wrapped air tight in plastic and sealed with Teflon tape or wax	None	NA
Permeability	ASTM D2434			
Soil moisture	ASTM D2216			
Particle size distribution	ASTM D422			
Organic content	ASTM D2974			

1 ICP metals include antimony, barium, beryllium, cadmium, chromium, copper, nickel, silver, thallium, and zinc.
2 Can be combined with total ICP metals sample jar.
3 Specific method will be identified after the laboratory has been selected.

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orientation of the sample is known. When possible, the samples will be hand carried to the laboratory in an upright vertical position to maintain the *in situ* orientation and to minimize sample disaggregation.

After the geotechnical samples have been collected, the core samples will be packaged for transport to the geotechnical laboratory. The core will be preserved by placing it in split PVC pipe and wrapping it with plastic wrap or in a core box. This will insure that the friable sections of the core will remain intact and that the core will not dry out prior to analysis. A chain-of-custody (COC) form will accompany the sample at all times. The continuous core samples will be transported to the laboratory where they will be slabbed and photographed with sufficient precision to identify lithologic detail (approximately 0.5 foot of photo per 1.0 feet of core). The photograph will be labelled by borehole number and sequentially by depth interval. In addition, the geotechnical engineering laboratory will run a GR log on each continuous core, as described in Section 2.6. If the sample is suspected of being hazardous, the laboratory will temporarily store the sample in a container provided by ES. Disposal of this container will follow all applicable laws and regulations.

3.1.2 Pilot Hole Sampling

A 180-foot deep pilot hole will be drilled at each well cluster location, as outlined in Section 2.4, to determine screen intervals for each of the wells. Samples will be collected for lithologic description.

3.1.3 Soil Sampling

Soil samples for chemical analysis will be collected in the vicinity of up to twelve private wells logged and sampled in this project. Soil samples will only be collected near wells that are determined to have contaminated groundwater. At each of these locations, four grab samples will be collected for analysis at depths of 0, 1, 2.5, and 5 feet. Lithologic logging is described in Section 2.4.3.

Soil samples will be collected from the surface (0 feet below ground level) using a decontaminated hand trowel or shovel. Samples for VOC analyses will be quickly containerized in a manner that minimizes volatilization of potential contaminants. To collect the remaining samples, two to four times the required sample volume will be adequately mixed in a decontaminated stainless steel bowl. Gravel and vegetation will be removed from the soil. The sample containers will be filled and the remaining contents of the bowl will be discarded. Samples to be analyzed for VOCs will not be homogenized or composted.

A decontaminated, manually operated subsurface sampler will be used to collect the shallow subsurface (1, 2.5, and 5 feet below ground level) soils. There are two equipment options: the Environmentalist's Sub-soil Probe (ESP) subsurface sampler, which pushes a thin plastic-lined sampler into the ground, and a hand auger. The ESP sampler is capable of collecting soil samples from depths of up to 15 feet. Disadvantages of this method are that small rocks stop the advance of the probe, and the plastic probe liners contain phenols that are characteristically picked up in chemical analyses. Rocks can also hinder or stop the advance of a hand auger.

Both of these methods may be utilized to collect samples. In addition, a power-driven auger may be used to advance the hole if necessary. Samples collected with the ESP probe will be shipped to the laboratory in the plastic probe liners. Samples collected with the hand auger will be collected as described above.

Soil samples will be analyzed for volatile organic compounds (SW-8260); semivolatile organic compounds (SW-8270); total arsenic (SW-7060; total mercury (SW-7471); total selenium (SW-7740); total lead (SW-7421); total ICP metals (SW-6010); and chromium VI (to be determined). Sample volume and preservation requirements are listed on Table 3.1. Ten percent of all soil samples will be field replicates. Field replicates are further described in Section 3.4.5.

Soil samples for chemical analyses will be marked to identify boring and depth, and cooled on ice to 4 °C for preservation. The sample jars will also be marked with analyses to be performed, date and time of collection, and initials of samplers.

3.1.4 Sediment Sampling

Sediment samples for chemical analyses will be collected from approximately twenty locations along Soldier Creek. Sediments will be collected only where groundwater recharges from the stream. Hence, this task will be performed based on Task 3, Soldier Creek streamflow survey. Sediment samples will be collected at 0, 1, 2, 3, and 5 feet below ground level at each of the locations.

Samples will be collected as described above in Section 3.1.2 or with sediment sampling devices. The 0-foot samples may be collected with a decontaminated hand trowel or with a decontaminated sampling dredge. The manually operated subsurface soil sampler described above or a hand core sediment sampler will be used to collect the remaining sediment samples.

Sediment samples will be analyzed for volatile organic compounds (SW-8260); semivolatile organic compounds (SW-8270); total arsenic (SW-7060); total mercury (SW-7471); total selenium (SW-7740); total lead (SW-7421); total ICP metals (SW-6010); chromium VI (to be determined); cation exchange capacity (SW-9080); total organic carbon (SW-9060); and pH (SW-9045). Chromium III will be determined by subtracting chromium VI results from total chromium results. The holding time for chromium VI is only 24 hours. Ten percent of all sediment samples will be field replicates. Field replicates are further described in Section 3.4.5. Sample volume and preservation requirements are listed on Table 3.1.

3.1.5 Groundwater Sampling

Groundwater samples will be collected from up to 39 wells, including up to 12 privately-owned domestic wells and 27 base-owned monitoring wells. As much as is possible, the privately-owned wells will be sampled using the procedures for sampling the base-owned monitoring wells. Abandoned private wells are preferred for sampling, but in some cases it may be necessary to remove a pump or to collect a sample from a faucet.

At least one complete set of water level measurements will be made over a single 10-hour period for all wells involved in the project. The relative elevation difference will be determined and reported to within ±0.5 feet, between any stream, lake, or open body of water, and wells within 300 feet of these features.

Before sampling begins, sample containers will be prepared with appropriate labels and preservations. Groundwater sample volume and container requirements are shown in Table 3.2.

The initial well purging and sampling will take place at least 14 days after well development is completed. Private wells will not be developed. Before each monitoring well is purged and sampled, the water level will be measured within ±0.01 foot with respect to the reference point on the top of the casing. The air in the breathing zone will be checked with a PID every time a casing cap is removed.

After the water level is recorded, the well will be purged to remove the stagnant water. Private wells that are not abandoned will not be purged. Either a PVC bailer (EPA, 1992) or a submersible pump will be used to purge the well. All purging and sampling equipment will be decontaminated prior to use following the procedures described in Section 2.9. Purging and sampling will be performed in a manner that minimizes the agitation of sediments in the well and formation. Equipment will not be allowed to free-fall into the well.

At least three well casing volumes of groundwater will be removed from each monitoring and private well prior to sampling. A casing volume differs from a pore volume in that it includes the volume of water within the well casing only. A pore volume includes the casing volume and the volume of water within the filter pack. The temperature, pH, and conductivity will be measured and recorded after each casing volume is removed during purging. The sample may be collected after three casing volumes have been removed and the temperature, pH, conductivity, color, and odor have stabilized. These parameters will be considered stable when pH varies ±0.1 unit, temperature varies ±0.5 °C, and conductivity varies ±10 mhos/cm or less during the removal of at least three well volumes. If these parameters do not stabilize, the sample will be taken after six casing volumes have been removed. Calibration of the pH, temperature, and conductivity meters is discussed in Section 4.4. Disposal of water generated during purging is described in Section 2.10.

Samples will be collected after the water level has recovered to 80 percent of its static level, or 16 hours after completion of purging, whichever occurs first. When a low-yield monitoring well is pumped or bailed dry before three well pore volumes have been removed, the sample will be collected as soon as the volume of recovered fluid is sufficient for sampling.

Groundwater samples will be collected in order of increasing contamination when possible, using a PVC bailer (EPA, 1992). The cleanest wells will be sampled first and the most contaminated wells will be sampled last. Careful use of the bailer will minimize sample agitation and contact with air. A clean length of nylon cord will be used for raising and lowering the bailer in each well.

Groundwater samples will be analyzed 129 priority pollutants (except dioxin and asbestos) including volatile organic compounds (SW-8260); semivolatile organic compounds (SW-8270); total arsenic (SW-7060); total lead (SW-7421); total ICP

Table 3.2 Sample Containers, Preservatives, and Holding Times for Water Samples
Tinker AFB SCGW RI/FS

Parameters	Method	Sample Container	Preservative	Holding Time
Volatile organic compounds	SW-8260	Three 40-mL glass vials with Teflon-lined septa	HCl to pH<2 (approx. 4 drops) Cool to 4°C	14 days
Semivolatile organic compounds	SW-3550/ SW-8270	Two 1-liter amber glass bottles with Teflon-lined lids	Cool to 4°C	Extract within 7 days of collection, and analyze within 40 days of extraction
Total ICP metals[1] (recoverable)	SW-3050/ SW-6010	One 1-L plastic bottle	HNO_3 to pH<2 Cool to 4°C	180 days
Total arsenic (recoverable)	SW-7060	One 500-mL plastic bottle[2]	HNO_3 to pH<2, Cool to 4°C	180 days
Total lead (recoverable)	SW-3020/ SW-7421	One 500-mL plastic bottle[2]	HNO_3 to pH<2 Cool to 4°C	180 days
Total mercury (recoverable)	SW-7470	One 500-mL plastic bottle[2]	HNO_3 to pH<2 Cool to 4°C	28 days
Total selenium (recoverable)	SW-7740	One 500-mL plastic bottle[2]	HNO_3 to pH<2 Cool to 4°C	180 days
Total chromium (VI)	SW-7195 - SW-7198[3]	One 500-mL plastic bottle	Cool to 4°C	24 hours
Total cyanide	SW-9010	One 1-L plastic bottle	0.6 grams of ascorbic acid, NaOH to pH>12, Cool to 4°C	14 days

1 ICP metals include antimony, barium, beryllium, cadmium, chromium, copper, nickel, silver, thallium, and zinc.
2 Can be combined with total ICP metals sample jar.
3 Specific method for chromium VI analyses will be determined after the laboratory has been selected.

metals (SW-6010); total mercury (SW-7470); total selenium (SW-7470); and total chromium VI (to be determined); and total cyanides (SW-9010). Chromium III will be determined by subtracting the chromium VI result from the total chromium result. Ten percent of all water samples will be field duplicates. Field duplicates are described in Section 3.4.6.

All sampling information will be recorded on groundwater sampling forms and entered into the IRPIMS database. The sampling form will record the following:

- Site identification and well number
- Time and date
- Sounded total depth of the monitoring well, depth to water before and after purging, actual volume of water purged, the thickness of any floating hydrocarbon layer, depth to water before and after sampling
- Field measurements of pH, temperature, and conductivity, and equipment calibration information
- Appearance and odor of the purged water, the condition of the well, weather conditions, and other comments.

Required preservatives will be added to the sample bottles before sample collection. The pH of preserved samples will be checked in the field by pouring a small amount of sample onto pH paper. The range of the pH paper will closely bracket the expected pH. The paper must not touch the sample inside the container. The pH of acidified VOC samples will not be checked.

Samples to be analyzed for VOCs will be collected first and immediately sealed in a container so that no headspace exists. Samples for volatile organic analyses will not be composited, homogenized, or filtered.

3.1.6 IDW Sampling

Investigation-derived wastes (IDW) will be sampled to characterize for disposal. Drill cuttings suspected by HNU or OVA readings, odor, or discoloration to be hazardous will be placed in drums and handled as described in Section 2.10. All other cuttings will be placed in roll-off type dumpsters as outlined in Section 2.10. Composite soil samples will be collected from these containers at the rate described in Section 2.10 and analyzed for TCLP volatile organics and metals. The extraction method for TCLP is SW-1311.

Water generated during the aquifer pumping tests will be sampled for characterization prior to disposal. The water will be analyzed for volatile organic compounds (SW-8260); semivolatile organic compounds (SW-8270); total lead (SW-7421); total cadmium, chromium, and nickel (SW-6010); and total chromium VI (SW-7195). Sample results will be requested within 24 to 48 hours.

No QA/QC samples will be associated with waste characterization sampling. Sample volume and preservation requirements are listed in Table 3.2.

3.2 SAMPLE HANDLING

3.2.1 Sample Containers, Volumes, Preservation, and Holding Times

Table 3.1 is a summary of the appropriate sample containers, preservatives, and holding times for soil samples. Table 3.2 is a summary of this information for groundwater samples.

3.2.2 Sample Identification

Each sample will be labeled with a gummed tag (Figure 3.1) which is marked with:

- Sample identification
- Time of collection (24-hour, four-digit)
- Date of collection (day, month, and year in the form dd-mo-yy)
- Sampler's initials
- Analytical method name and number
- Any field preparation of the sample (e.g., filtered)
- Preservation method.

The identification of samples collected from the monitoring wells will consist of the monitoring well number, beginning from MW1-79 TO MW1-87. To be consistent with the base well numbering system, the shallowest well will be "B," the intermediate well will be "A," and the deep well of each cluster will be "C." An example groundwater sample ID is MW1-79B. To distinguish piezometers and pumping wells, the piezometer wells will have the affix "P" and the pumping test wells "PW." Therefore, MW1-91PWA is the intermediate zone pumping well, and MW1-88PB is the shallow piezometer number 88.

Sediment sample IDs will consist of the designation "SE" and the location number. The top depth of the sampling interval will follow in parentheses, e.g. SE5 (3.0′). Lithologic core samples will be identified with "LC", e.g. LC2 (150.5′).

The identification of groundwater samples collected from private wells will be the street address of the well, not to exceed ten characters. For a sample collected from a well at 123 Main Street, the sample ID may be 123Main. The soil samples will have the same ID as the associated groundwater sample, but the depth will follow in parentheses, e.g. 123Main (2.5′).

Samples collected from all locations will be identified on the sampling log by using the same information recorded in the environmental sampling information file (BCHSAMP) data fields, as defined in the *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook*, version 2.2 (USAF, 1991).

3.2.3 Sample Packaging and Shipping

Samples will be shipped and delivered to the designated laboratory for analysis daily or every other day, as required. Before samples are shipped, the ES field team leader (or designee) will contact the laboratory to inform them of shipments.

CUSTODY SEAL

Engineering-
Science Inc.

Date ____________

Signature ____________

CUSTODY SEAL

Engineering-
Science Inc.

Date ____________

Signature ____________

ES ENGINEERING-SCIENCE, INC.
AUSTIN, TEXAS

SAMPLE I.D.	DATE
	TIME
ANALYSIS	SAMPLER
	PRESERVATIVE

FIGURE 3.1
CHAIN-OF-CUSTODY
SEAL AND
SAMPLE LABEL

TINKER AIR FORCE BASE

U.S. Department of Transportation shipping requirements will be followed when applicable. Based on historical data (B&V, 1993), environmental samples collected off-base in the past generally contained less than 10 parts per million (ppm) of any contaminant. EPA (1982) identifies these samples as "low concentration" samples. If samples collected during the SCGW RI/FS are suspected to contain between 10 ppm and 15 percent of any contaminant, the sample is potentially hazardous according to DOT regulations and must be shipped without ice. If the concentration of the contaminant is suspected to be above 15 percent, the sample will be packed without ice and shipped according to DOT regulations for hazardous samples.

The samples will be shipped in ice chests by an overnight carrier such as Federal Express. Glass bottles will be wrapped with polynet and bubble wrap and placed in an airtight plastic bag. A COC form will be sealed in a plastic bag and taped to the inside lid of each ice chest. Each chest will be sealed with tape and a custody seal (Figure 3.1). A diskette containing environmental sampling information in IRPIMS format will be included with the COC form of one ice chest per day.

The holding time for chromium VI samples is only 24 hours. Prior arrangements must be made with the laboratory when collecting samples for this analysis. Overnight delivery may not be appropriate due to time constraints. In those cases, the samples must be hand delivered or shipped by air carrier.

3.3 SAMPLE CUSTODY

COC records provide a means of tracing each sample from the time of collection through shipment and final analysis, producing a written record of all persons handling the samples. A sample is defined as being under one's custody if it is in one's possession or in view after being in one's possession, or if that person locked the sample up or put it in a designated secure area.

The COC form will list sample identification, matrix, date and time of collection, preservatives used, analyses requested, name of sample collector(s), and the signature of each person receiving and relinquishing the samples. Figure 3.2 is an example COC form. The "Remarks" column of the COC form will be used to record additional information which may be of use to the laboratory for prescreening the samples, and to note any sample preservation methods used.

A COC record will accompany the samples at all times. When transferring possession of samples, the individual relinquishing and receiving the samples will sign, date, and note the time on the record. This record documents transfer of sample custody from the sampler through any intermediary custodians to the laboratory.

Samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis with a separate signed COC record included in each sample box or cooler. Shipping containers will be custody-sealed for shipment to the laboratory by overnight express delivery. Bills of lading will be retained as part of the permanent documentation in the task manager's file. The original COC will accompany the shipment, and a copy will be retained by the field supervisor.

Figure 3.2 Chain-of-Custody Form

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE
AUSTIN, TEXAS
ES

PROJECT NAME/LOCATION

PROJECT NUMBER

SAMPLER(S):

(Signature)

CARRIER ☐ Federal Express ☐ UPS

Other ______

AIRBILL OR CARRIER ID #

Date	Time	Loc. ID	Sample ID/Desc.	Sample Type	Matrix	Sampling Method	Begin Depth	End Depth	NUMBER OF CONTAINERS	PRESERVATIVE / ANALYSIS REQUIRED	FIELD LOT CONTROL NUMBER: Ambient Condition Blank / Equipment Blank / Trip Blank / Cooler Letter	REMARKS

Relinquished by: (Signature) Date Time	Relinquished by: (Signature) Date Time	Relinquished by: (Signature) Date Time
Received by: (Signature) Date Time	Received by: (Signature) Date Time	Received by: (Signature) Date Time

White : laboratory returns with data; **yellow** : laboratory copy; **pink** : sampler copy.

chaino.dwg

The original COC form will accompany the samples to the laboratory. The laboratory will make and maintain a file copy, and the completed original will be returned to the task manager as a part of the final analytical report. This record serves to document sample custody transfer from the sampler to the shipper, and to the laboratory. Upon receipt of samples, the laboratory will provide a written report to the field investigation manager summarizing the conditions of samples, sample numbers received and corresponding laboratory numbers, and the estimated date for completion of laboratory analysis.

3.4 QUALITY CONTROL SAMPLES

Six types of field QC samples will be collected during the entire investigative effort. ASTM Type II reagent-grade water will be used for field blanks, trip blanks, ambient condition blanks, equipment blanks and for decontamination. This water will have analytical data or a manufacturer's certification that verifies the quality of the water and shows it to be free of analytes and contaminants that may interfere with the required laboratory analyses. The water's electrical conductivity will be less than 1.0 micromho per centimeter (at 25°C). Type II reagent-grade water will be purchased and stored only in glass or Teflon containers with Teflon caps or cap liners.

3.4.1 Field Blanks

Field blanks will be collected to check the purity of the type II reagent-grade water. Two field blanks will be collected over the course of the project. Field blanks will be analyzed for the same parameters as the environmental samples. The sample ID for field blanks will be FIELDQC. The sample type will be MB1 (materials blank).

3.4.2 Trip Blanks

One trip blank will accompany every cooler shipped to the laboratory which contains soil and/or water samples to be analyzed for VOCs. A trip blank is a VOC sample bottle filled in the laboratory with type II reagent-grade water, transported to the site, handled like a sample, and returned to the laboratory for analysis. If there is more than one sampling team, only one team will carry a trip blank to the sampling locations. Trip blanks will not be opened in the field. This blank will be analyzed for VOCs only. The sample ID for trip blanks will be FIELDQC. The sample type will be TB1.

3.4.3 Ambient Conditions Blanks

Ambient conditions blanks will be collected during each VOC groundwater sampling round. An ambient conditions blank is type II reagent-grade water that is poured into a sample container at a sampling site. An ambient conditions blank does not need to be taken at every site. When possible, ambient conditions blanks will be collected when samples are collected downwind of possible VOC sources such as active runways. This blank will be analyzed for VOCs only. The sample ID for ambient conditions blanks will be FIELDQC. The sample type will be AB1.

3.4.4 Equipment Blanks

One equipment blank will be collected on each day of groundwater sampling. An equipment blank is type II reagent-grade water that is poured into the sampling device, transferred to a sample bottle, and transported to the laboratory for analysis. This blank will be subjected to all laboratory analyses requested for environmental samples at the site at which the blank is collected. The sample ID will be FIELDQC. The sample type will be EB, numbered sequentially starting with 1 (e.g., EB1).

3.4.5 Field Replicate Samples

Ten percent of all soil samples will be replicates. A field replicate is a single sample divided into two equal parts for analysis. Both the sample and its replicate will be analyzed for the same constituents in the laboratory. The sample identification for each replicate sample will be the same as the identification for the environmental sample. Due to IRPIMS data requirements, the identity of the replicate sample cannot be disguised. The sample type will be FR1.

3.4.6 Field Duplicate Samples

Ten percent of all water samples will be field duplicates. A field duplicate is one of two samples collected independently at a sampling location during a single act of sampling. Both the sample and its duplicate will be analyzed for the same constituents in the laboratory. The sample identification for each duplicate sample will be the same as the identification for the environmental sample. Due to IRPIMS data requirements, the identity of the duplicate sample cannot be disguised. The sample type will be FD1.

3.4.7 Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Samples

Five percent of all soil, water, and sediment samples will be MS/MSD samples. Generally MS/MSD samples will be collected when a duplicate or replicate sample is being collected. MS and MSD samples each require the same sample volume that the environmental sample requires. The sample identification is the same as the environmental sample. The sample type is MS1 for the matrix spike, and SD1 for the matrix spike duplicate.

3.4.8 Split Samples

Ten percent of all soil, sediment, and water samples will be split samples for Tinker AFB, at their request. Split samples will be collected in the same manner that duplicates and replicates are collected. These samples will be provided to Tinker AFB, along with a COC form. The sample identification is the same as the environmental sample.

3.5 SAMPLE ANALYSIS SUMMARY

A summary of the project soil analyses is shown on Table 3.3. A summary of the project water analyses is shown on Table 3.4.

Table 3.3 Summary of Project Soil/Sediment Analyses
Tinker AFB SCGW RI/FS

Parameter	Analytical Method	Task 4 Lithologic Cores	Task 5 Well Cluster	Task 7 Aquifer Pump Tests	Task 8 Soil Sampling	Task 9 Sediment Sampling	Estimated Number of QA/QC Samples				Total
							Trip Blanks	Replicates	Matrix Spikes	Matrix Spike Duplicates	
Chemical:											
Volatile organic compounds	SW-8260				48	100	10	18	9	9	194
Semivolatile organic compounds	SW-8270				48	100		18	9	9	184
Arsenic	SW-7060				48	100		18	9	9	184
Lead	SW-7421				48	100		18	9	9	184
ICP metals	SW-6010				48	100		18	9	9	184
Chromium VI	SW-7195 - SW-7198				48	100		18	9	9	184
Mercury	SW-7471				48	100		18	9	9	184
Selenium	SW-7740				48	100		18	9	9	184
Cation exchange capacity	SW-9080		36	3		100					139
Total organic carbon	SW-9060		36	3		100					139
pH	SW-9045		36	3		100					139
Geotechnical:											
Atterberg Limits	ASTM D4318	24									24
Soil moisture	ASTM D2216	24									24
Permeability	ASTM D2434	24									24
Particle size distribution	ASTM D422	24									24
Organic content	ASTM D2974	24									24

Notes:
Totals do not inlcude sampling that may be necessary for IDW characterization.
Tasks not listed do not include soil sampling.

Table 3.4 Summary of Project Water Analyses
Tinker AFB SCGW RI/FS

Parameter	Analytical Method	Task 2 Private Well Survey	Task 5 Monitoring Well Construction	Task 7 Aquifer Pump Tests	Estimated Number of QA/QC Samples						Total
					Trip Blanks	Equipment Blanks	Ambient Blanks	Duplicates	Matrix Spike	Matrix Spike Duplicates	
Volatile organic compounds	SW-8260	12	36	3	22	22	2	6	3	3	109
Semivolatile organic compounds	SW-8270	12	36	3		22		6	3	3	85
Total arsenic	SW-7060	12	36	3		22		6	3	3	85
Total lead	SW-7421	12	36	3		22		6	3	3	85
Total mercury	SW-7470	12	36	3		22		6	3	3	85
Total selenium	SW-7740	12	36	3		22		6	3	3	85
Total ICP metals*	SW-6010	12	36	3		22		6	3	3	85
Chromium VI	SW-7195 - SW-7198	12	36	3		22		6	3	3	85
Total cyanides	SW-9010	12	36			18		5	3	3	77

* ICP Metals include antimony, barium, beryllium, cadmium, chromium, copper, nickel, silver, thallium, and zinc..

Notes:

Tasks not listed do not include water sampling.
Totals do not include sampling that may be necessary for waste characterization, except for that required for the aquifer pump tests.

SECTION 4

FIELD EQUIPMENT CALIBRATION, MAINTENANCE, AND DECONTAMINATION

The following sections describe the equipment used in the field to measure specified parameters. Procedures for equipment calibration, maintenance and decontamination are summarized on Table 4.1.

Field measurements may be made using the following monitoring equipment:

- HNu photoionization detector (PID)
- Organic vapor analyzer (OVA)
- Sensidyne one-stroke pump and colorimetric tubes
- HMX271 combustible gas indicator
- Hydac® conductivity/temperature/pH meter
- Hach® Turbidimeter
- Electric water level indicator
- Hermit® transducer and data logger
- Leupold and Stevens Model 420 Recorder
- Portable flume, weir or volumetric container, and stop watch
- Current meter.

Before use, field monitoring instruments will be calibrated on a schedule according to the manufacturer's specifications. A copy of the operations manual will be kept with all field monitoring equipment. The operator must understand the limitations of each instrument and the possible sources of error. Furthermore, the operator must ensure that the equipment is in good working order and functioning properly. All calibration activities will be noted in a calibration logbook.

4.1 HNU PHOTOIONIZATION DETECTOR AND ORGANIC VAPOR ANALYZER

Monitoring for total organic vapors and gases in the field will be conducted using the HNu photoionization detector or the OVA. The HNu measures up to 2,000 parts per million (ppm) organic vapors in the air and will be used for various field screening techniques.

Table 4.1 Calibration Methods and Frequency
Tinker AFB SCGW RI/FS

Parameter	Equipment	Calibration	Source of Calibration Standards	Equipment Maintenance	Equipment Decontamination
Volatile organic compounds (VOC)	Photoionization detector (PID).	Daily according to manufacturer's instructions with ambient air (considered 0 mg/L) and isobutylene gas (100 mg/L).	Commercially available, premixed, in cylinders.	Avoid prolonged use in humid environments; keep probe away from dirt or free water; recharge battery.	Replace instrument filter; clean lamp.
VOC	OVA.	Daily, and every 2-3 hours during use, methane in air.	Scott specialty gases.	Charge batteries, keep probe out of liquids.	Not applicable.
Explosive gases	Combustible gas indicator.	Daily with known gas and concentration; daily testing in known explosive environment (gas tank) and zero adjustment in clean environment.	Commercially available, battery.	Keep inlet away from dirt or free liquids, recharge battery.	Not applicable.
pH	Hydac pH temperature, and conductivity meter.	Daily with known pH buffer solutions.	Commercially available.	Keep instrument face dry. Keep pH probe moist. Replace battery when necessary.	Squirt pH probe with water after every use.
Conductivity	Hydac pH, temperature, and conductivity meter.	Daily with Solution of known conductance.	Commercially available.	Keep instrument face dry. Replace battery when necessary.	Clean sample cup with water and paper towel after every use.
Water level in well	Water level indicator.	Check against steel tape.	Commercially available.	Replace battery when necessary.	Squirt probe with water after every use.
Stream flow velocity	Price Type AA and Pygmy current meter.	Before measurement check the vane, cup, pivot bearing, and shaft for damage, wear, or misalignment	Spin the cup wheel in the air; it should turn for at least 1 minute.	Clean and oil meters daily while in use.	Clean meter with water.
Stage	Water stage recorder.	Check transducer, clock, and recorder every visit to the station.	Calibrate against staff gage for transducer and clock for timer.	Return to supplier.	Not applicable
Stage	Staff gage.	Ensure gage is vertical after storm.	Resurvey the datum.	Not applicable	Not applicable

During drilling of soil and monitoring well borings and monitoring well installation, the PID will be used periodically to monitor the breathing zone, drill cuttings, borehole and undisturbed core samples. Headspace analyses of soil samples retrieved with a core sampler during drilling will also be tested with the HNu or OVA. All readings made with the HNu or OVA will be recorded either in the field logbook or directly on the field boring logs.

During well development, groundwater sampling, and surface soil sampling, the HNu or OVA will be used to monitor the breathing zone, and readings will be recorded in the field logbook. Furthermore, immediately after the monitoring well cap is removed, a reading will be taken inside the top of casing. The frequency of air monitoring for these activities is defined in the project health and safety plan (ES, 1993b). Prior to use of the HNu or OVA for air monitoring, personnel will be thoroughly familiar with site-specific action levels defined in the health and safety plan.

The HNu photoionization detector or OVA will be calibrated according to the user's manual at least once a day prior to use in the field. The standard calibration gas for the HNu is isobutylene, which may be obtained in canisters from an environmental sampling equipment supplier.

4.2 SENSIDYNE ONE-STROKE PUMP AND TUBES

If the concentration of organic vapors in the breathing zone exceeds 1 ppm above background, benzene and vinyl chloride Sensidyne tubes will be used to determine whether these compounds are present. These two compounds have the lowest permissible exposure limit (PEL) of all suspected contaminants on site. Sensidyne tubes are compound specific and may be used to determine if the compound is present and to quantify the concentration. If needed, Sensidyne tubes will be used during drilling activities, monitoring well installations, subsurface soil sampling, groundwater sampling, and the geophysical surveys. The frequency of ambient air monitoring is listed in the health and safety plan.

The tube is physically broken open at one end, and ambient air is manually drawn through the system to obtain a direct reading. Sensidyne tubes do not require calibration.

Each Sensidyne tube contains a reagent system designed to undergo a chemical reaction with a particular substance. Since chemicals and chemical reagents are not stable indefinitely, each box of detector tubes is stamped with an expiration date. The tubes are suitable for use through the last day of the month of expiration. Tubes used beyond the expiration date cannot be relied upon to give accurate results.

To guarantee the validity of the tube expiration date, Sensidyne tubes should always be stored in the original package at room temperature. A note on the package indicates a maximum storage temperature of 25°C (77°F). Excessively low (less than 35°F) or high (greater than 77°F) temperatures during storage will be avoided, and the tubes will not be subjected to light for prolonged periods.

Detector tubes are tested according to NIOSH method TCA/A-012, "Certification Requirements for Gas Detector Tube Units," for the Safety Equipment Institute certification program. Furthermore, each manufacturer's detector tubes are tested as a unit by an independent third party laboratory accredited by the American Industrial Hygiene Association (AIHA).

The Sensidyne one-stroke pump and tubes require no general maintenance.

4.3 HMX271 COMBUSTIBLE GAS INDICATOR

The HMX271 combustible gas indicator will be used to measure the lower explosive limit (LEL) in work areas. The LEL of a combustible gas or vapor is the lowest concentration by volume in air which will explode when there is an available ignition source. During field activities that can potentially generate sparks, such as drilling or welding, the breathing zone and the air in and around the borehole or well will be periodically monitored with the HMX271 combustible gas indicator. Furthermore, during field activities around enclosed spaces the breathing zone will also be monitored for the presence of combustible gases and vapors.

The HMX271 combustible gas indicator takes continuous and simultaneous measurement of combustible gases, oxygen levels, and hydrogen sulfide concentrations. The HMX271 should be calibrated with pentane according to the user's manual prior to field work each day.

If the HMX271 is used to measure hydrogen sulfide, it will first be calibrated with the appropriate calibration gas.

The HMX271 combustible gas indicator will be maintained in the field by wiping the unit clean after every use, storing the unit in a safe protected case, and recharging the battery on a daily basis or as use dictates.

4.4 HYDAC CONDUCTIVITY, TEMPERATURE, PH METER

General water quality parameters will be periodically tested during well development and purging and groundwater sampling using a Hydac conductivity, temperature, pH meter or equivalent. The Hydac conductivity, temperature, pH meter will be calibrated according to the user's manual each day prior to use. The meter will be recalibrated periodically during days of extended use.

4.5 TURBIDITY METER

Turbidity will be periodically measured during well development and purging and groundwater sampling using a Hach Turbidimeter or equivalent. The Hach Turbidimeter will be calibrated in the manner and at the frequency specified in the user's manual.

4.6 WATER LEVEL INDICATOR

The depth to groundwater will be measured in each monitoring well with an electric water level indicator. Depth to water will be measured from a surveyed point on top of casing and recorded in the field logbook.

The fiberglass tape on the water level indicator may stretch over extended periods of use. Therefore, the accuracy of the water level indicator will be checked in the field against a calibrated steel measuring tape. Calibration of water level indicator(s) will be performed once prior to use.

The following procedures will be followed for proper maintenance of the water level indicator:

1. Keep probe clean and free of silt or mud. Rinse after every use.
2. Before sending the unit to the field, make sure it is functioning properly. If not, replace batteries and try again. If water level indicator is still not functioning properly, send back to manufacturer for repair.

The probe on the water level indicator must be thoroughly rinsed with deionized water prior to taking each water level measurement. This procedure will prevent cross contamination at the site. If gross contamination is observed on the water level indicator probe, it will be washed with Alconox and water and a paper towel or scrub brush.

4.7 HERMIT TRANSDUCER AND DATA LOGGER

A Hermit 2000 data logger will be used to measure the water level changes in the test wells during the aquifer pumping tests. The Hermit data logger consists of a transducer which is lowered into the well and a data logger which records the water level data in a digital format. The pressure transducer measures the amount of water above it in the well casing. The transducer is delicate and must be placed in the well with care. It should be placed in the well at least one hour prior to setting up the test or collecting data to insure that the transducer has stabilized with the water temperature and that the transducer and cable have settled into a stable position.

The depth of placement of the transducer will be based on site specific conditions. The transducer must not be submerged more than two times the depth range printed on the transducer body, or it will be permanently offset.

Proper maintenance of the Hermit 2000 data logger requires the following procedures:

1. Wipe clean the readout unit on a daily basis.
2. Protect the instrument by storing it in the padded carrying case.
3. Decontaminate the transducers and cable after each use.
4. Keep pores in transducers clean of foreign particles, such as silt and mud.
5. Check battery prior to field use.
6. Send to manufacturer after extended period of use for certification that equipment is functioning properly.

4.8 LEUPOLD AND STEVENS MODEL 420 RECORDER

The recorder and pressure transducer (Submersible Depth Transmitter II) are factory calibrated. Should the recorded data show abnormality, the recorder and transducer will be sent back to Leupold and Stevens, Inc.

4.9 PORTABLE FLUME, WEIR, OR VOLUMETRIC CONTAINER WITH STOP WATCH

The flume, weir, and volumetric container are manufactured according to hydraulic equations. They are either factory calibrated or calibrated against other methods. Proper use of these discharge measuring devices do not require calibration. In case of damage or wear, they should be replaced with a new one.

4.10 CURRENT METER

The Price type AA and pygmy current meter is factory calibrated. The meter should be maintained and cleaned according to USGS procedures. Before a field trip, the meter should be spinned in the air. If the meter (cups) stops within one minute, the meter should be cleaned and oiled or returned to manufacturer.

SECTION 5

FIELD QA/QC PROGRAM

This section is a summary of the field QA/QC program, covering identification and description of control parameters used during field operations, acceptance criteria for each parameter controlled, and corrective actions required for field or laboratory personnel in the event control limits are exceeded. Field measurement parameters, control checks, control limits and corrective actions are identified in Table 5.1.

5.1 CONTROL PARAMETERS

During sampling activities, six types of field quality assurance quality control (QA/QC) samples will be collected, as described in Section 3.4. In addition, MS/MSD samples will be collected for laboratory QA/QC. Split samples will be collected for Tinker AFB.

1. Two field blanks will be collected over the course of the project to verify the quality of the type II reagent-grade water.
2. One trip blank will accompany every cooler of soil and water samples sent to the laboratory for the analysis of volatile organic compounds. The trip blank will be analyzed for VOCs only.
3. One ambient conditions blank will be taken during each VOC sampling round when samples are collected downwind of possible VOC sources such as active runways or engine test cells.
4. One equipment rinsate blank will be taken by each sampling team on each day of sampling. This blank will be analyzed for the same chemical constituents as all environmental samples collected at the site.
5. Ten percent of all water samples collected will be field duplicates. Duplicate samples will be analyzed for the same constituents as the original in the laboratory.
6. Ten percent of all soil samples will be field replicates (single samples divided into equal parts for analysis). Replicates will be analyzed for the same constituents as the original in the laboratory.
7. Ten percent of all soil, sediment, and water samples will be split samples for Tinker AFB at their request. Split samples will be analyzed for the same constituents as the original under the direction of Tinker AFB.

Table 5.1 Control Parameters,
Control Limits, and Corrective Actions
Tinker AFB SCGW RI/FS

Measurement Parameter	Control Checks	Control Limits	Corrective Actions*
pH	Measure buffer pH at least following every other measurement.	Buffer measurements within ±0.2 units of actual values.	Recalibrate pH meter; check batteries and probe condition.
Electrical conductance	Measure standard solution daily.	±10 percent of actual value.	Replace or replatinize probe; verify that meter zeros and red-lines properly; check batteries.
Temperature	Check measurement.	±1°C	Replace thermometer or correct temperature readings.
Volatile organics (photoionization detector)	Measure standard gas at least daily.	±5 percent	Replace dust filter; clean lamp; check battery.
Explosive gases	Measure calibration standard daily, test periodically in known explosive environment (gas tank) and check zero in clean environment.	Adjust meter to read exact standard value. Control limit for fresh air is ±1 percent.	Recalibrate meter; check battery; replace sensor.
Water level (water level indicator)	Measure weekly against tape measure when in regular use.	±0.02 feet	Replace meter tape.

* Required if control limits not achieved.

Monitoring instruments used in field activities will be calibrated, adjusted, and maintained according to the manufacturer's specifications at specific intervals to maintain accuracy within necessary limits. The field equipment calibration, adjustment and maintenance procedures and schedules are discussed in Section 4. Equipment calibration and maintenance will be documented in the field logbook.

5.2 CONTROL LIMITS

Precision objectives for field measurements are listed in Table 5.2. Acceptance criteria for calibration and maintenance of field monitoring instruments are discussed in Section 4.

5.3 CORRECTIVE ACTIONS

Corrective actions for field measurements are listed in Table 5.1. If control limits are exceeded during calibration and maintenance of field monitoring instruments, corrective action will be taken. Corrective action plans are discussed in Section 4. In the event that field QA/QC control limits are exceeded, the field logbook will document exceedance of criteria and discuss subsequent corrective actions.

Table 5.2
Precision Objectives for Field Measurements
Tinker AFB SCGW RI/FS

Measurement Data	Precision Objective	Corrective Action
pH	Consecutive readings agree within ±0.1 pH units	Recalibrate
Temperature*	Visually inspect the instrument before each use	Replace thermometer
Conductivity	±0.1 mS/cm	Recalibrate
PID readings	±15 percent from calibration readings at specified span setting	Return instrument for maintenance
Water level measurements	±0.01 feet	Return instrument for service

* No corrective action as no standard measurement is available in the field.

SECTION 6

RECORD KEEPING

ES will maintain field records sufficient to recreate all sampling and measurement activities and to meet all IRPIMS data loading requirements. The requirements listed here apply to all sampling and measuring activities. Requirements specific to certain activities are listed in the section that addresses that activity.

Information gathered during field activities will be recorded with indelible black or blue ink in a permanently bound hard-covered notebook with sequentially numbered pages. Corrections will be crossed out with a single line, dated, and initialed. All entries will be legible. Pages will never be removed from a logbook. All partially used pages will be lined out to prevent data entry at a later date. Any missing pages will be explained in the corresponding field book. The explanation will be signed by at least two people with supervisory capacities.

Field documentation will consist of one master site logbook, one or more field logbooks, field forms, and sample logs and labels. Site and field logbooks provide a daily handwritten record of all field activities. The site logbook is a master record of all activities, and entries are usually made at the end of each work day. Field logbooks are detailed daily records that are kept in real time.

The following items will be included in the site logbook:

- List of all field logbooks and person(s) assigned
- Weather, temperature, names and titles of personnel present
- Name, title, organization, and purpose of each visitor to the site
- Brief outline of activities for each day and references to the appropriate logbooks, forms, computer files, and records for details
- Record of the number of samples collected at each site by medium, footage of drilling and/or well construction, the name of the laboratory(ies) to which samples were shipped, airbill numbers of sample coolers shipped, and other pertinent summary information
- Specific comments on problems that occurred during daily activities, their final resolution, and anticipated impact
- Record of telephone calls pertaining directly to the decision-making process of the field investigation.

Entries in the field logbook will be signed by the responsible person at the end of each page. The following information will be entered in the field logbooks:

- Date and time; weather; names, titles, and organizations of personnel performing the task
- Description of site activities in specific detail or an indication of what forms were used
- Description of any field tests and results that have been conducted, with a reference to any forms used
- Description of samples collected and any duplicates or replicates, including sample IDs, analytical parameters, preservation methods, and sample custodian
- Equipment used, including serial number, time of calibration, corresponding general comments, and description of any failures or breakdowns.

A separate logbook will be kept to log all equipment calibrations and maintenance.

Forms will be used to record information during drilling, well construction, well development, purging and sampling. Figure 6.1 is a drilling log form. Figure 6.2 is an aboveground monitoring well completion form and Figure 6.3 is a flush monitoring well completion form. Well completion information for double and triple-cased wells will be documented on well completion forms with similar formats as the single-cased well completion forms. All the recorded information will be the same with the addition of information specific to the multiple-cased wells. Figure 6.4 is a well development form, and Figure 6.5 is a well purging and sampling form. Figures 6.6 and 6.7 are discharge measurement forms.

A well/boring record will be compiled for each boring or monitoring well site. It will be a complete record of what ES has accomplished at the site. The well/boring record for each well will include the drilling log, monitoring well construction diagram, well development form, and well sampling form.

Figure 6.1 Drilling Log Form

PAGE OF

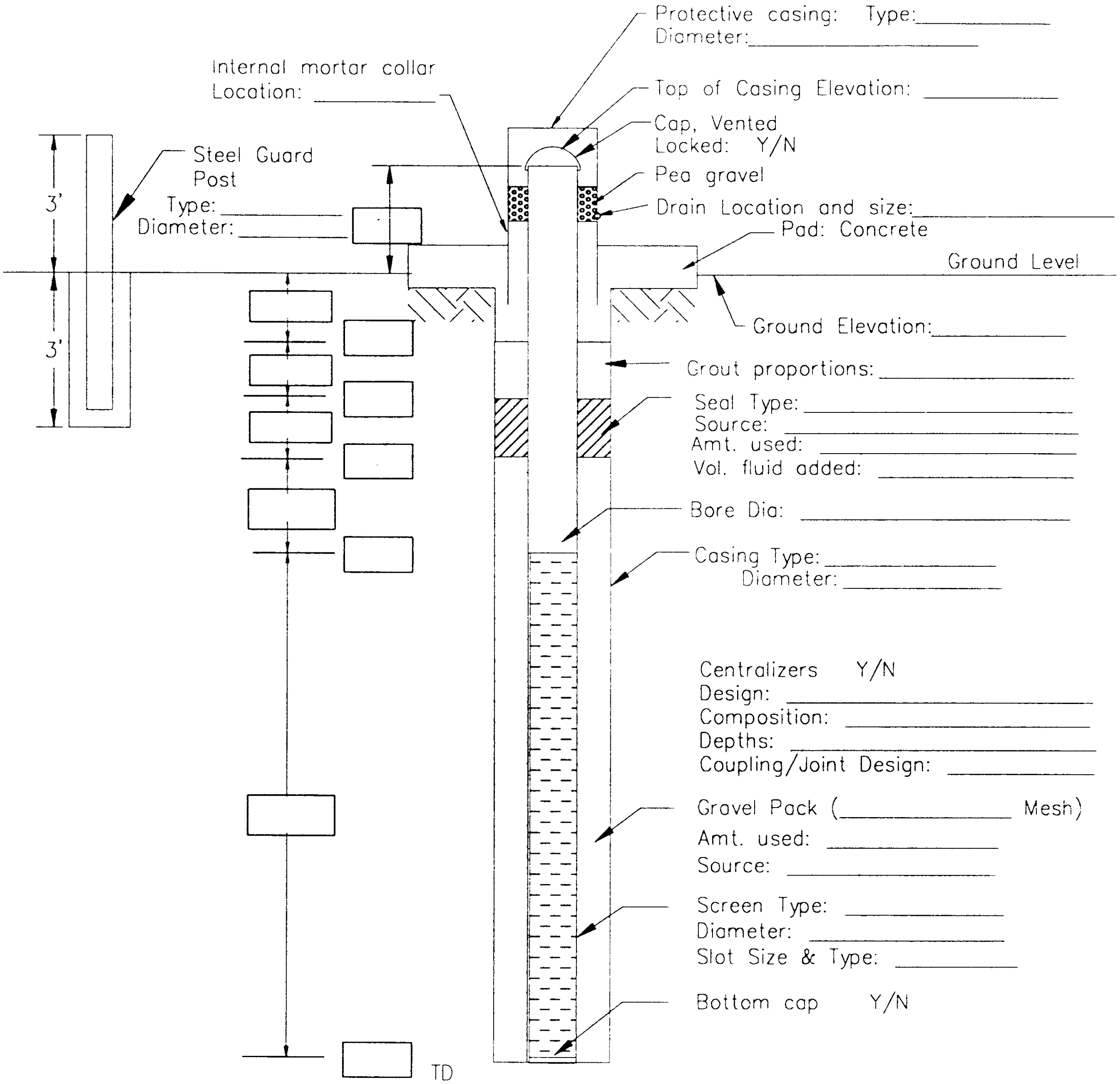
DRILLING LOG	ENGINEERING-SCIENCE, INC.	REF LOGBOOK:

CLIENT:	WELL OR BORING NO.:
PROJECT:	SITE LOCATION:
DRILLING CONTRACTOR:	DRILLING RIG:
DRILLING METHOD:	DRILLER:
SAMPLING METHOD:	LOGGED BY:
BOREHOLE DIA.:	WATER FOUND (ft-BGL):
DRILLING START:	TOTAL DEPTH (ft-BGL):
DRILLING END:	FINAL COMPLETION DATE:
ABANDONMENT: DATE: GROUT WT:	

DEPTH (feet)	SAMPLE INTERVAL	RECOVERY	HNU SCAN (ppm)	LITHOLOGIC DESCRIPTION	HNU OVA HDSP (ppm)	SAMPLE INFO.	COMMENTS

Installation: ______________________
Well ID: ______________________
Comp. started ___/___/___ (: m)

Project no. ______________________
Drilling contractors: ______________
Comp. finished: ___/___/___ (: m)



Backfill plug material: ______________
Interval: ______________
Any additives: ______________
____

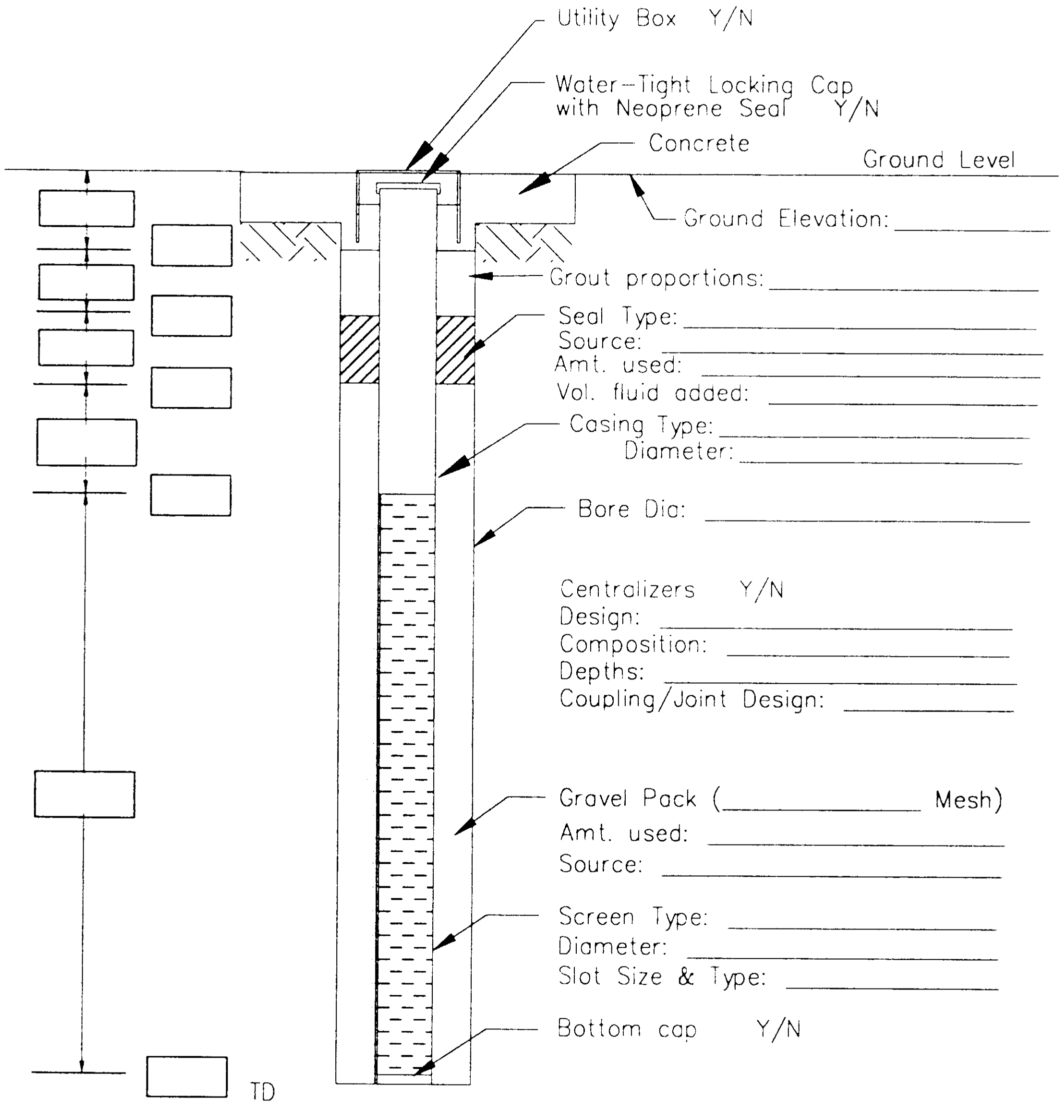
Development Information
Water level before development: ______________
Water level after development: ______________

FIGURE 6.2
ABOVEGROUND
MONITORING WELL
COMPLETION FORM

TINKER AFB, OKLAHOMA

RISAMPWL 11/23/93

Installation: ______________________ Project no. ______________________
Well ID: ______________________ Drilling contractors: ______________________
Comp. started __/__/__ (: m) Comp. finished: __/__/__ (: m)



Backfill plug material: ______________
Interval: ______________
Any additives: ______________
____

Development Information
Water level before development: ______________
Water level after development: ______________

FIGURE 6.3
FLUSH
MONITORING WELL
COMPLETION FORM

TINKER AFB, OKLAHOMA

RISAMPWL 11/23/93

Figure 6.4 Well Development Record

WELL DEVELOPMENT RECORD

Tinker AFB	TINKR	AFID
Location identification	______	LOCID
Date	__/__/__	LOGDATE
Time	______	LOGTIME

Diameter (Inches)	Volume (Gals/ft)
2	0.16
4	0.65
6	1.47
8	2.61
10	4.08
12	5.88
14	8.00

Development Method

bail pump surge air lift

type ______

surge method, if used ______

VOLUME MEASUREMENTS

Casing inside diameter	______	in
Static water level	______	ft
Total casing depth	______	ft
Length of water column	______	ft
Volume of water in well	______	gal
Volume of water in annulus	______	gal
PURGE VOLUME (calculated at right)	______	gal
Bailer length	______	ft
Bailer inside diameter	______	in
BAILER VOLUME	______	gal
Number of bailers for ____ volumes	______	bailers

Volume of water in annulus = ____ ft. water column × [(____ gals/ft. borehole volume − ____ gals/ft. casing vol.) ___% porosity] = ____ gals

Volume of water in well = ____ ft. water column × ____ gals/ft. casing vol. = ____ gals

Development volume = ____ ft. water column × 1 / 2 / 3 / 4 / 5 borehole volumes (*circle one*) × [(____ gals/ft. casing vol.) + (___gals/ft. borehole volume − ____ casing volume) ___% porosity] = ____ gals

PURGE RECORD

Time	Volume/ Bail No.	pH	Elec Cond	Visual Appearance

Total volume removed: ______

Static water level 24 hours afterward: ______

Weather: ______

Developed by: ______

Figure 6.5 Groundwater Sample Record

GROUNDWATER SAMPLE RECORD

Tinker AFB	TINKR	AFIID
Location identification	______	LOCID
Date	__/__/__	LOGDATE
Time	______	LOGTIME
Sample beginning depth	______	SBD
Sample ending depth	______	SED
Lot control number	______	LOTCTLNUM
Sampling method	______	SMCODE
Sampling matrix	______	MATRIX
Sample type	______	SACODE
Analytical method	______	ANMCODE

Preservation ______________________

Diameter (Inches)	Volume (Gals/ft)
2	0.16
4	0.65
6	1.47
8	2.61
10	4.08
12	5.88
14	8.00

VOLUME MEASUREMENTS

Casing inside diameter	______	in
Static water level	______	ft
Total casing depth	______	ft
Length of water column	______	ft
PURGE VOLUME (calculated at right)	______	gal
Bailer length	______	ft
Bailer inside diameter	______	in
BAILER VOLUME	______	gal
Number of bailers for ____ volumes	______	bailers

Purge volume = _____ ft. water column × _____ gals/ft casing vol. × 1 / 2 / 3 / 4 / 5 volumes (*circle one*) = _____ gals

PURGE RECORD

Time	Volume/ Bail No.	Temp °F	pH	Elec Cond		Visual Appearance

Weather: ______________________________ Sampled by: ______________

450RB\AU405\TKRIT6-5

Figure 6.6 Discharge Measurements Form (USGS form 9-275)

9-275G
(Mar. 1972)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

DISCHARGE MEASUREMENT NOTES

Meas. No. ....
Comp. by ....
Checked by ....

Sta. No. ....

....

Date ...., 19..... Party ....
Width .... Area .... Vel. .... G. H. .... Disch. ....
Method .... No. secs. .... G. H. change .... in .... hrs. Susp. ....
Method coef. .... Hor. angle coef. .... Susp. coef. .... Meter No. ....

GAGE READINGS				
Time		Recorder	Inside	Outside
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Type of meter ....
Date rated .... for rod, other.
Meter .... ft. above bottom of weight.
Spin before meas. .... after ....
Meas. plots .... % diff. from rating ....
Wading, cable, ice, boat, upstr., downstr., side bridge .... feet, mile, above, below gage, and ....
Check-bar, found ....
changed to .... at ....
Correct ....
Levels obtained ....

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section ....
Flow .... Weather ....
Other .... Air ....°F@ ....
Gage .... Water ....°F@ ....
.... Record removed .... Intake flushed ....
Observer ....

....

Control ....

....

Remarks ....

....

....

G. H. of zero flow .... ft.

GPO : 1974 O - 561-095

FORM NO.
TWO

Date .... 19 ...... **DISCHARGE MEASUREMENT NOTES**

....River, at...

Dist. from initial point	Angle coef-ficient	Depth	Depth of observation	Revolutions	Time in seconds	VELOCITY At point	VELOCITY Mean in vertical	VELOCITY Mean in Section	Area	Mean Depth	Width	Discharge

Figure 6.7

FORM 9-207
(Rev. 11-69)

UNITED STATES DEPARTMENT OF THE INTERIOR

Station No. ____________

Geological Survey (Water Resources Division)
DISCHARGE MEASUREMENT SUMMARY SHEET

Discharge measurements of ____________ during the year ending Sept. 30, 19____

No.	Date	Made by	Width Feet	Area Sq. ft	Mean Velocity Fps	Gage Height Feet	Discharge Cfs	Rating____ Shift adj. Feet	Percent diff.	Method	Number meas. sections	Gage height change Feet	Time Hr	Meas. rated	Time Temp. °c	GZF or Susp.	Outs. Ght	Remarks

Copied by____ Computed by____ Checked by____

E5/AU40511/ESPFIG6-7.WK1

SECTION 7

SITE MANAGEMENT

The Tinker Air Force Base remedial project manager (RPM) and point of contact (POC) is John Schroeder, P.E., (telephone number 405/736-2941). The Tinker AFB contracting officer is Gordon Mohon (telephone number 405/739-3367).

Tinker AFB will provide ES personnel and their subcontractors with personnel identification badges, vehicle passes, and/or entry permits within 1 week of written notification of personnel names, citizenship, and state of birth for American citizens. The base will provide escorts when access to restricted areas is required. The base will issue digging permits to ES prior to the commencement of drilling operations.

The base will also provide a location at Tinker AFB for a mobile trailer field office within 25 feet of a 110/115-volt AC electrical outlet for the trailer.

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